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ERATOSTHENES.—III.

By WILLIAM H. PICKERING.

Dr. Maggini's Drawings.

The two figures, Plate XIX, illustrating this paper are the work of the well-known Italian observer of Mars. They were secured with a 9-inch objective and are interesting as being the first complete drawings of Eratosthenes published, since the preliminary ones by the late Sir William Christie and the writer. They are valuable not only as confirming the changes already described, as occurring within and around this crater when the sun is near its meridian, but also as showing one or two features not hitherto detected.

Figure 1 was drawn the night before full moon, and although the writer has been at pains in every article he has published of late on lunar changes, to point out that these dark markings cannot be shadows, since they are visible when the moon is full, yet we find two well known foreign astronomers and mathematicians attributing them to "changing angle of illumination" and "shifting shadows." If so, why do they always appear conspicuously at full moon? Why do they not always appear the same when the moon is of the same age in different lunations? How explain the dark marking, mentioned later, that advances towards the setting sun? The fact that shadows cannot be seen at full moon would seem to be almost elementary. While the writer does not insist on any particular explanation of these changing markings, yet he does insist that they are not due to "shadows" or "changing illumination." As stated in previous articles he believes that they are probably due to vegetation, but that question we will discuss later. Under each drawing is given the date, the colongitude, and the quality of the seeing.

The second drawing was made four days after full moon, and three days after the sun had crossed the meridian of the crater. Many changes will be noted, but perhaps the most striking one is the disappearance of a dark heart-shaped marking found to the left of the central peaks, which was visible near full moon. Some of the larger dark markings or "fields" remind one strongly of some of the southern "seas" on Mars. Bright lines resembling the Martian "bridges" have also developed across them, notably one in the lower right hand portion of the second figure, and several to the right of the central peaks.

Instead of comparing the differences between these two drawings

however, it may be more interesting to compare them with three of those made by the writer, and published in POPULAR ASTRONOMY for last August under the heading "Eratosthenes II." These three are there designated as Figures 4, 5 and 6. Dr. Maggini's Figure 1 was drawn but 8° of colongitude, that is but 16 hours of time, later in the lunation than the writer's Figure 4. We should naturally expect them to resemble one another, and such we find indeed to be the case. His capacity for doubling the Martian canals where the writer sees them single is also here exhibited in at least three places in the upper right hand quadrant. But what is more interesting is that he finds a nest of canals, or "runs" as we call them in the case of the moon, in the precise spot which we have designated as the "run region" at the top of the figure towards the right. While the agreement in location of all of these runs is not exact, yet the general resemblance is clear, and the difference is probably due chiefly to the difficulty of the objects depicted.

Dr. Maggini's Figure 2 lies 29° of colongitude after our Figure 5, and 11° earlier than our Figure 6. Nevertheless, it resembles the former more closely than it does the latter, showing that during the interval separating Figure 2 from Figure 6, or between colongitude 139° and 150°, very rapid changes of detail appear to occur. The runs in the run region of Figure 2 resemble those in the run region of Figure 5, and the drawings of both observers show, and mutually confirm the fact that between colongitudes 78° and 110° the changes in the narrow, canal-like markings of the run region are also very marked. A third drawing of Dr. Maggini's, made at colongitude 120° but not here shown, represents two bright bridges in the Northern field as prolongations of two dark runs on the inner wall of the crater. The Northeastern field is shown much as it is in Figure 5, with no indication of the bright bridges represented so clearly in Figure 2.

In our article entitled "Eratosthenes II," we described and showed the position of the two runs Main and Cross situated in this same run region, the latter pointing directly towards the central peaks, while the former as shown in Figure 2 is the heavy run at right angles to it. In Figure 1 this angle is more nearly 60°. Dr. Maggini's drawings therefore confirm the drawings and azimuths published in the earlier article, showing how Main shifts its azimuth by gliding across the surface of the moon, while Cross is fixed in position. It may be pointed out that visible motions on the moon are very rare, most of the changes observed being due to a gradual darkening or brightening of the surface. This is true also of the markings on Mars.

ERRORS OF NEWSPAPER CORRESPONDENTS.

Since considerable attention has been paid to these observations of lunar change in both the American and European press, it may be well to correct in this place some misapprehensions that seem to have oc-

curred. In the first place the crater is not Eratosthenes II, but Eratosthenes, the numeral merely indicating that the paper reviewed is the second one published on this crater. In the second place the investigation is not based on photographs as has been stated, but on drawings, which are capable of depicting much finer planetary detail than photographs. It is true however that photographs confirming the drawings have been taken. Some of these were published in connection with the first paper on this crater (POPULAR ASTRONOMY, 1919, **27**, 579). In the third place the talk of violent volcanic eruptions, of snow storms, blizzards, etc., sweeping across the surface of the moon is all rubbish. Both volcanic activity and snow have been detected, but the regions affected are extremely small, and the observations would be difficult if not impossible at most northern observatories. No large snowy areas occur on the moon excepting in the polar regions.

In this connection it may be pointed out to the newspaper correspondents that, contrary to popular impression, not only are moderate sized telescopes better than very large ones for planetary observations, on account of atmospheric conditions, as has been abundantly proved by the results of the last thirty years on Mars, but also that all the most experienced planetary observers when working with large apertures voluntarily reduce them at times, by means of stops placed in front of their objectives.

Northern observers furthermore labor under an additional disadvantage. Whenever good seeing occurs in the temperate zones it is only in the summer season, when partly tropical conditions prevail there. When the moon is full, or when the planets are nearest us in opposition, they are always low in summer, and high in winter. They are therefore always low at the only times when favorable atmospheric conditions occur and are therefore never well placed for temperate zone observation. Good seeing in the north sometimes lasts into the early autumn. At this season the moon is high when it is at the first quarter. Consequently, northern observers should be able to observe this phase of the moon to more advantage than any other.

THE SUGGESTION THAT THESE CHANGES ARE DUE TO VEGETATION.

The important point which it was desired to bring out in my second paper on this crater was that a regularly recurring, systematic, monthly change, not due to shadows, did occur upon the moon. This fact we may now consider as confirmed by at least two other astronomers. The *explanation* of these changes that we shall finally adopt, on the other hand, is a matter of little consequence comparatively, although of some interest to many people.

What has been chiefly criticized in the various reports hitherto made has been the explanation offered of the changes; doubt has not been expressed, by those competent to judge, of the actual occurrence of the changes themselves. Now the real and definite reason why I have

referred these changes to vegetation is simply because that is the explanation almost universally adopted at the present time for the changes observed on Mars, changes which seem to be in all respects identical with those occurring upon the moon. It therefore appeared natural to apply the same explanation to the lunar phenomena. If a more plausible explanation can be discovered for the lunar changes it will probably be found also to apply to the case of Mars.

The chief criticism of this hypothesis hitherto made, is that it would be impossible for terrestrial vegetation to exist upon the moon. The obvious reply to this is that such a suggestion has never been made by the writer. Indeed I believe no one has entertained such an idea for the last hundred years or so. The suggestion that such vegetation should exist on the Moon is as ridiculous as it would be to expect an oak tree to grow at the bottom of the sea, or seaweed to grow on the summit of a mountain peak. Both certainly would very shortly die.

As the writer has distinctly stated, the lunar vegetation must be very different from that found on the earth, and this too is what all of the observations indicate. Some writers have stated that it must be of a very low order of organization, while others have referred to its leaves and branches. Both of these views I think are mistaken. The fact is that we know nothing whatever about what it is like, or whether its organization should be described as high or low as compared with our own. Apparently some of it may even move about. It is known that certain large intestinal worms sometimes live inside of horses, and that the only oxygen that they can obtain comes from their food. These worms are sufficiently highly organized to possess brains and nervous systems. If such is the case there would seem to be no reason why the lunar vegetation should not be able similarly to draw any oxygen that it might require from the soil. Carbon dioxide would readily be supplied by the volcanoes, as is the case on our own planet.

With regard to the density of the lunar atmosphere, let us assume that the refraction of a star at the Moon's limb amounts to 1″. This is about the value that the Greenwich observations imply, although the exact value is very uncertain. The refraction at the Earth's limb would be double the horizontal refraction, or 3600″. In order to compute the ratio of the densities of their atmospheres we shall assume that it is proportional to their refractions, and inversely as their diameter, and the value of gravitation at their surfaces. The resulting value is 1/150, corresponding to a density of 5 millimeters of mercury at the moon's surface. This would only permit water to remain in a liquid state when near the freezing point. If the pressure were less than this, this would account for the fact that we do not find it at the edge of the snow, as is the case on Mars.

On account of the low gravitational force on the surface of the moon, it is doubtful if either oxygen or nitrogen exists there in a free state in appreciable quantities. Water vapor and carbon dioxide would

also constantly escape from its atmosphere, and could only be retained there by constant renewal from the volcanic craters. Let us suppose that the moon had originally as large a supply of water in proportion to its mass as the earth, that is 1/80 as much, and let us suppose further that the earth by cooling has expelled through volcanic action all of its internal water to form our oceans. The total original supply of water within the moon would then have been 6,000,000 cubic miles. If now a cube of water measuring 1000 feet on a side had been lost from the moon's atmosphere and replaced from the interior through volcanic action every year, for the past four hundred million years, the supply would now be about half exhausted. So there may well be plenty of water still in the interior of the moon.

The density of the earth's atmosphere is halved for every 3.5 miles that we ascend. Owing to the small gravitational constant, the density of the atmosphere of the moon would only be halved after an ascent of twenty-one miles. The lunar atmosphere cannot therefore be confined exclusively to the crater floors as some persons have imagined.

As on Mars the color of the vegetation is mostly gray. Indeed that is so with an appreciable portion of our own vegetation when seen through a few miles of our atmosphere. A criticism that has frequently been made is that the lunar vegetation flourished and died with almost unbelievable rapidity. This rapidity would not surprise anyone who had gathered mushrooms, and had thoroughly cleaned up a small field one day, for the next morning when he went out, he would find just as many mushrooms there as there were the day before. Under favorable terrestrial conditions a bamboo shoot will grow 9 inches in twenty-four hours.

Let us consider now the real objection to the hypothesis of vegetation. This is the fact that while much of it requires several days of sunlight in order to develop, there is certainly some that appears of a dark gray color the moment the sun shines on it, and which almost appears as if it had developed during the lunar night. It perhaps resembles some of our spring flowers that sometimes force their way up through the late snows of winter. Moreover there is none of it, as far as the writer has been able to determine, that is certainly affected by its passage through the earth's shadow during a lunar eclipse. An eclipse also appears to produce but little effect on the snow, although it is believed that the white area around Linné increases about 0.6″ in diameter under these conditions. These facts should be determined with all possible accuracy, and then given their full weight. In the mean time, as has been previously stated, any other plausible explanation of the observed phenomena will be greeted with interest.

The Shifting Run.

This is undoubtedly the most remarkable and unexpected feature of this remarkable crater. As determined by micrometric measurements, described more fully in my second paper, this run advances up

hill in a direction inclined at an angle of about 45° *towards* the setting sun. Those astronomers who thoughtlessly described it as a shifting shadow must explain to us definitely first how a shadow can move towards the setting sun, and secondly what shape the object casting such a shadow must have, before we can accept their explanation of it as correct. It moves transversely through something over its own breadth, leaving a white area behind it. It moves at a different speed in different portions of the same lunation, and moreover at a different speed during the same portion of different lunations. It seems to follow no definite law. Its speed appears to be uninfluenced by a coming eclipse. There is no evidence of foresight or prediction in its motions, which appear to be a law unto themselves. These are most readily and rapidly indicated by the constant changes occurring in its position angle, or direction, with regard to two bright craterlets in its immediate vicinity. Other runs in its neighborhood do not change.

Its maximum linear velocity is 132 feet per hour, so that its change of position may readily be detected in the course of a single evening. The total distance that it travels in different portions of its length varies between one and three miles in ten days. In general its dimensions are six miles by one. It is curved at first, but soon straightens itself out. In darkness it may be described as darker than the average run, but becoming somewhat lighter when it broadens out at noon, as if composed of separate individual units, and then narrowing sharply and becoming darker again later. It may not be due to lunar vegetation, and it is clearly of a kind very different from our own, but it certainly seems to indicate life of some sort or another upon the moon.

Luxor, Egypt, January 31, 1922.

RECENT DEVELOPMENTS IN OPTICAL GLASS MAKING IN AMERICA.

By DONALD E. SHARP.

The first good telescopes available to the early astronomers, where great light-grasping power was requisite, were telescopes employing specula made by William Herschel during the latter part of the eighteenth century. Although Herschel in 1789 succeeded in producing a speculum four feet in diameter, at that time the largest successful telescope objective lens measured only about three and one-half inches in diameter. Inspired by offers of prizes and honors from the French Academy of Sciences, many workers tried their hands at the manufacture of large objective discs, but it was several decades before any of even twelve inches diameter were produced. The application of a method of stirring to produce homogeneity in the glass, led to the possibility of obtaining large chunks free from many heavy striae, and in

the middle part of the nineteenth century Bontemps in England, and Feil in France succeeded in making objective discs almost thirty inches in diameter but only of mediocre quality.

These discs were made by the moulding process originated by Guinand. A large rough chunk of glass was selected from a regular optical glass melting, and all defects possible to eliminate were cut out. A fireclay mould coated inside with powdered alumina or kaolin was used as a form for the disc. The chunk was placed in this mould, and the whole put in a large furnace, which was gradually brought up to the softening temperature of the glass, which then softened and filled out the mould. The annealing was accomplished by claying up all holes in the furnace, and allowing it to cool very slowly. It was often necessary to inspect, cut out bad spots, and remould several times before obtaining a good disc.

In spite of the success of the new school of optical glass makers at Jena. in improving glasses, and design of lenses, there had been produced few objective discs measuring larger than thirty inches in diameter even in the latter part of the nineteenth century. The difficulty of obtaining large chunks of flawless glass for objectives led to an increased interest in the reflecting telescope, and it was soon realized that absence of chromatic aberration was not the only advantage to be gained by using a parabolic mirror in place of an achromatic lens. Due to the difference in the way the discs were used, it was evident that striae, stones and bubbles which would ruin an objective would be without any effect on a reflector. Indeed, almost the only requirement for a good reflector disc is that it be made of stable glass, sufficiently thick to cause no trouble from flexure, and well enough annealed that the finished mirror may maintain its original zonal error during slight changes in temperature. Thus it was possible to make discs of enormous sizes for use in reflecting telescopes, and this type of instrument became, consequently, very popular with the astronomers.

The largest telescope in the world, in use at Mount Wilson Observatory in California, is a reflector of 101 inches diameter. The enormous light gathering power of this instrument has revealed to astronomers many hitherto unsuspected secrets. Although the entire mechanical equipment of this telescope was made in this country, the one vital part, the glass disc, came from France. This in itself is not unusual, however, for when this telescope was built all the optical glass, whether for lenses or reflectors, came from abroad. Moreover, the scientists of America were led to believe that optical glass could never be made in this country.

Attempts had been made years ago to manufacture optical glass in the United States. History records the fact that several glass manufacturers at different times spent thousands of dollars in experimentation, yet until recent years none was successful in making high grade optical glass. Upon the outbreak of the world war in 1914, America,

the largest manufacturer and user of optical instruments, found herself confronted with a shortage of optical glass. Several of the larger instrument manufacturers at once started intensive experiments in making optical glass, but progress was very slow. When the United States entered the war, it soon became evident that we must have a source of optical glass to supply the range finders, binoculars, periscopes, and other optical instruments so necessary to the army and navy. At this time, the National Research Council, despairing of any immediate results from the glass manufacturers, obtained the coöperation of the Geophysical Laboratory of Washington, D. C. The scientists of this laboratory took complete charge of the plants which had started experimental work, and the work was undertaken with renewed vigor. Thanks to the tireless efforts of these scientists the problems were soon solved, and tons of glass were supplied in time for use by our military forces.

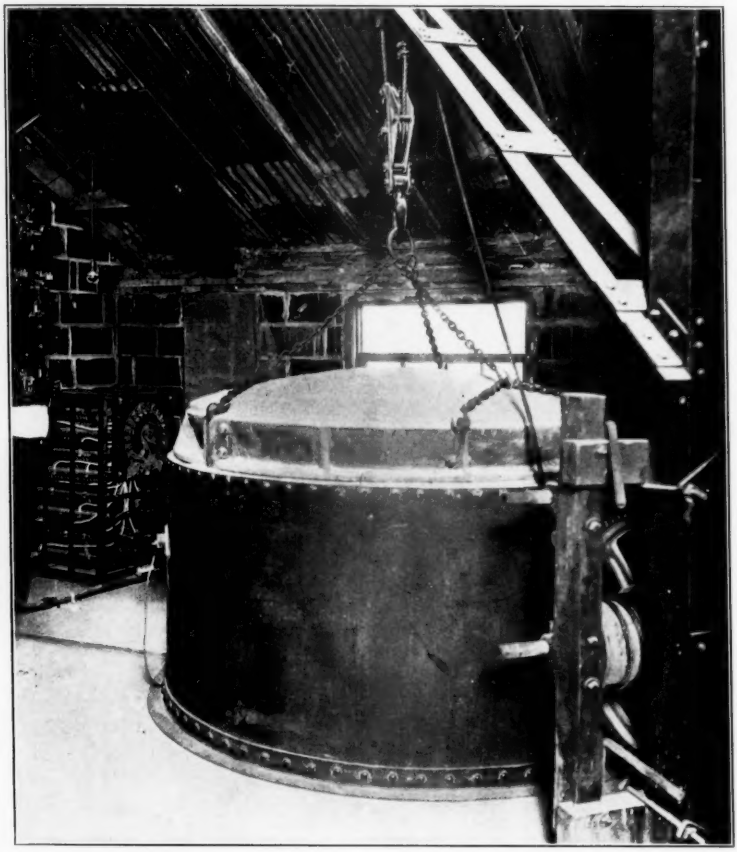
The glass made during war time was nearly all fashioned into comparatively small lenses, for there were few instruments requiring over a three-inch aperture. The development of the optical glass industry along the lines of large telescope discs consequently did not take place until after the signing of the Armistice. During the first part of 1919 there were manufactured in this country by the optical glass plant of the Spencer Lens Company of Buffalo, several successful twelve-inch objective discs made by the softening and moulding method. These were successfully annealed in a furnace designed especially for particularly careful work.[1] An attempt to extend the scope of the work by making a twenty-inch disc resulted unfavorably, for the disc was broken in the annealing process due to the fact that the annealing furnaces were too small for this large disc, which therefore had to be cooled in a melting furnace. At this time, it was decided that an electric furnace would be necessary in order to cool the discs at the proper rate, and after collaboration with expert furnace manufacturers an order was placed for a special resistance furnace, with an automatic regulator capable of controlling the temperature to within a degree. At this time several orders for reflector discs in addition to some for refractor discs were obtained and the manufacture of both kinds was undertaken.

The electric furnace, although successful in the second trial on a twenty-three inch reflector disc, repeatedly proved a disappointment on a forty-inch size. It was, therefore, redesigned by the users and further experiments begun. Additional apparatus was invented to adjust automatically the temperature controllers originally furnished with the furnace , so that any cooling rate desired between two-tenths of a degree and one degree centigrade per hour could be obtaind.

In the meantime, the gas furnace equipment, which had been dis-

[1]D. E. Sharp, Jour. Am. Ceram. Soc. **4**, 597-607, (1921).

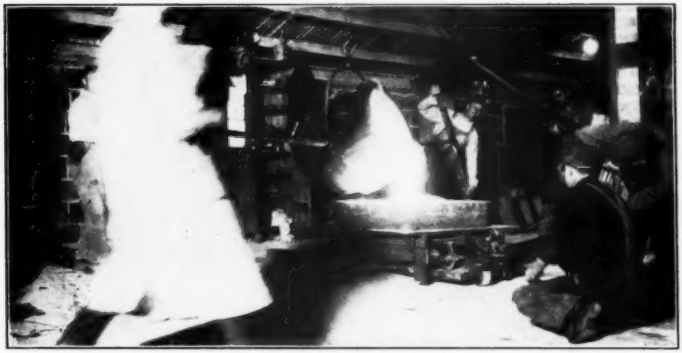
PLATE XX



ELECTRICAL ANNEALING FURNACE USED ON LARGE TELESCOPE DISCS.

(Factory of Spencer Lens Optical Co., Hamburg, N. Y.)

PLATE XXI



CASTING A LARGE TELESCOPE DISC.

GRINDING AND POLISHING A 40-INCH REFLECTOR DISC,
PRIOR TO INSPECTION FOR STRAIN.

carded as useless, was restored and redesigned. An automatic thermostat control, which was applicable to gas furnaces, was also devised. A trial of the two methods, gas and electricity, was started in December, 1921, and culminated in the recent announcement that both methods were successful.

Many have thought that the United States could never produce these enormous discs of glass, which in the rough weigh as much as a half ton in the case of the forty-inch size. The researches of the Geophysical Laboratory of Washington, D. C., made it possible to calculate the proper annealing temperature and cooling schedule, but the next problem was to obtain the desired conditions in the furnace.

Due to the careful heat treatment necessary during the annealing process, intricate and accurate instruments were necessary for regulating the temperature and as a result, constant and experienced supervision was required. The author, who directed the work, had as an associate Mr. Walter Rising, a chemist who had been thoroughly experienced in optical glass making. During the course of the work, it was found necessary to have a scientist close at hand during the night time, when the equipment was being watched by the workmen, so that any unusual occurrences could be taken care of promptly. Mr. Rising volunteered to assume the responsibility of the work during the night, and with this point in view caused an apartment to be fitted up in the factory close to the annealing furnaces. This apartment he occupied during the latter part of the work.

An innovation in the making of discs in America is the use of a low expansion glass. The actual kind of glass used in a reflector is of little importance, providing the glass possesses good weathering qualities. The use of crown glass involves however, a well known diffculty encountered in the use of reflecting telescopes, namely the effect of temperature changes. For example, when a mirror is heated or cooled by exposure to radiation, the shape of the surface changes, due to the expansion and contraction of the glass with temperature. In order to minimize the effect of changes of temperature, it is customary to place a large insulating chamber around the mirror in such a manner that considerable metal in the mounting of the telescope be included in the chamber. This device aids in reducing rapid changes of temperature.

It is an accepted experience that when these undesirable surface changes occur the resultant effect on the definition of the reflctor is on the average towards under-correction.[2] It has been suggested that this difficulty might be minimized providing the parabolic mirrors be made with a slight degree of over-correction. It is obvious, however, that it is preferable to eliminate as far as possible the cause of the under-correction, and this can now be accomplished by the use of low expansion glasses. It is now possible to obtain discs in this country

[2]J. S. Plaskett, Jour. Royal Ast. Soc. Canada **14**, 193, (1920).

having less than one-half the expansibility of the crown glass furnished in imported discs.

The first large American telescope to be made entirely in this country is that of the Steward Observatory of the University of Arizona. Doctor Douglass, the Director of the Observatory, has supervised the installation of the mounting which is already in place. He also purchased the largest reflector disc so far made in America—a forty-inch disc, which is now being finished by McDowell, successor to Brashear of Pittsburgh. The telescope will have a clear aperture of thirty-seven inches.

It has thus become possible this year for the first time to erect a large telescope made entirely in America. It is to be hoped that the United States will not stop at this, but that the future will see an all-American telescope rivalling the huge Mount Wilson reflector. At present a pair of twenty-four inch objective discs for the Alvan Clark Company are well under way and a pair of thirty-two inch objective discs are in the moulding. Complete details of the manufacture of both reflector and refractor discs will appear in the literature soon.
Spencer Lens Company Optical Glass Plant, Hamburg, New York.

AN OBSERVATORY FOR A 9^1_2-inch REFLECTOR.

By J. ERNEST G. YALDEN.

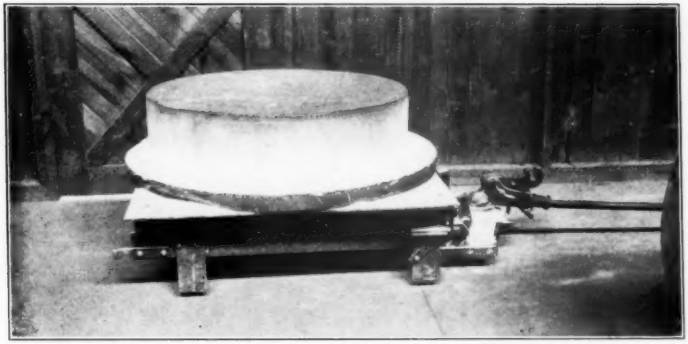
The following is a brief description, with working drawings, of a small observatory designed by me for Mr. George Waldo of Bridgeport, Connecticut, a member of the American Association of Variable Star Observers.

Mr. Waldo found upon inquiry that a dome of conventional design and sufficient size to house his telescope would cost $1200.00, while this observatory has been erected by a builder in a first class manner for approximately $600.00, not including extras such as electric wiring and interior fittings.

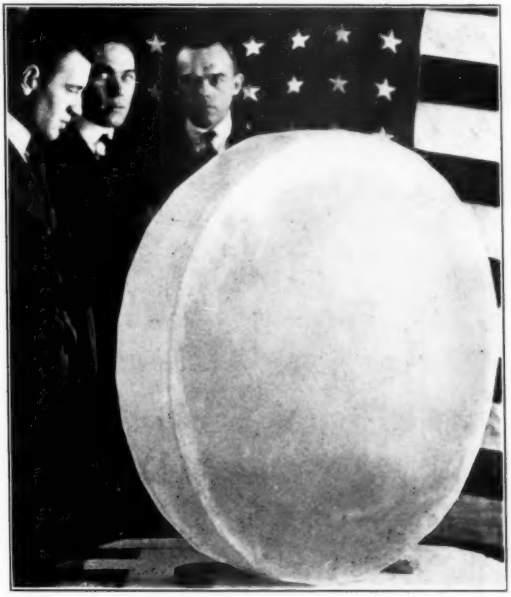
This type of observatory has some original features. It has all the advantages of the circular dome, and in addition its simplicity means cheapness of construction, and the possibility of an amateur handy with tools, being able to build a similar one without expert assistance. Again this type of dome possesses an advantage over the circular dome placed upon a square building, inasmuch as an accumulation of snow cannot prevent the same from revolving.

This objection to the circular dome can be obviated by placing it upon a circular building; but a square building possesses some advantages that must not be overlooked. These being ease and cheapness of construction, and the fact of the available corners for shelving and tables to hold astronomical paraphernalia.

PLATE XXII



40-inch Reflector Disc after Removing Sides of Mould.

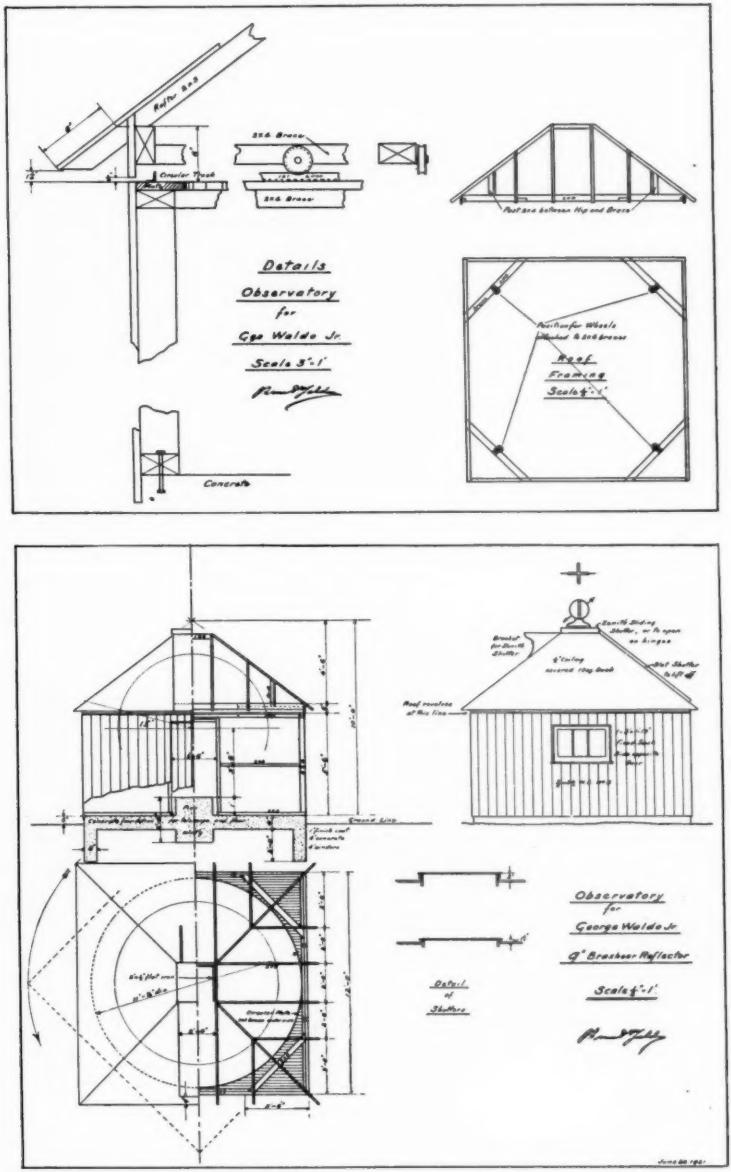


40-inch Reflector Disc Standing on Edge.

PLATE XXIII

THE OBSERVATORY WITH DOME OPEN.

THE OBSERVATORY WITH DOME CLOSED.



WORKING DRAWINGS FOR A SMALL OBSERVATORY.

In the working drawing the Zenith Shutter is shown to slide open horizontally, running on brackets fastened to the roof of the dome, but it may be made to open on hinges as shown in the photograph. (Plate XXIII).

This method may have some advantage in winter weather, and as the shutters in this observatory were made of galvanized iron, the Zenith Shutter was made to open in that manner.

SPECIFICATIONS FOR CARPENTRY AND MASON WORK.

1. Foundation to be set so that one side faces true (not magnetic) north.
2. Set two anchor bolts 5/8-inch diameter in each side (8 in all) to hold sill, and necessary anchor bolts set to template for telescope base.
3. No concrete to contain less than 1/8 of Portland cement, and all exposed surfaces to be finished smooth and true with coat of 2 to 5 cement mortar with small amount of lime if necessary to give neat appearance.
4. Timber: Posts 4 x 4, Studs 2 x 4, Sill 2 x 4, Plate 2 x 4, Braces 2 x 4 and Rafters 2 x 3, all dressed 4 sides spruce.
5. Cover outside of frame with ⅞ x 3½ N. C. sheathing M and B, batten door of same. Novelty siding may be used as a substitute. Window stock cellar sash fixed.
6. Cover roof with ½-inch N. C. ceiling dressed under side, and 10 oz. duck laid in lead and oil, and given second coat after laying. Fasten canvas with copper tacks. Circular plate of building to be 1⅛-inch pine.
7. Circular track to be 1½ x 1½ angle iron, firmly secured in place to support wheels on upper edge. Four wheels to be grooved edge galvanized steel block sheaves with ball bearings. Same to be fastened to side of roof braces with lag screws.
8. Fit reinforcing iron band around deck opening on top of roof, securely fastened to the 2 x 3 three sided frame.
9. Zenith and slot shutters may be of wood or galvanized iron.
10. As inside frame is to be exposed it shall be framed and erected in a neat manner with close and true joints, and boarding present a good undamaged surface on the interior.
11. In finishing shellac all knots before priming, and total of two coats of good lead and oil paint applied.
12. If owner desires inside finish, use Beaver Board with cypress rectangular strips over joints giving panel effect, and a plain surface.

WHAT ABOUT MARS?

By J. G. PORTER.

We shall have during next summer a comparatively favorable opportunity for studying the planet Mars, and in 1924 conditions will be still better, especially in the southern hemisphere. No doubt we shall hear a great deal from that school of astronomy which believes in the habitability of the planet, and it seems only fair that the more conservative view should also be set forth.

In the first place it ought to be recognized that the true interpretation of the surface markings on Mars can not be arrived at by visual or photographic observations alone. The nearest approach of Mars to the earth is about thirty-five million miles. At the next opposition

it will be forty-one million miles away. Assuming that a magnifying power of one thousand diameters can be employed, this still leaves the planet thirty-five thousand miles distant, or considerably more than the circumference of the earth. Of course higher magnification is possible, but beyond a certain point the advantage of increase in size is counterbalanced by the indistinctness and wavering of the image. It is safe to say that we can not at present, and probably never shall be able to see Mars in the telescope as clearly as we should with the naked eye at a distance of twenty-five thousand miles.

But what ought we to see in a landscape as far away as the whole circuit of the earth? Most persons have at some time looked off from a high hill or mountain. At thirty or forty miles all but the most salient features of the view disappear. It is true that conditions in viewing the moon or Mars are more favorable than in looking across the earth's surface at a distant landscape; for in the former case our line of sight traverses less of the denser portions of the atmosphere. Nevertheless the improbability that at a distance of several thousand miles one can see planetary details with sufficient clearness to judge of their true character must be perfectly evident to the candid mind.

This point can be brought out in another way. Mars at its nearest is more than 140 times as far away as the moon. A magnifying power of seven applied to the moon would be equivalent to a power of one thousand in the case of Mars. Look at the moon with a small opera glass, and compare the view with that shown by a powerful telescope. Then one will realize how little it is possible to actually distinguish on the Martian surface. A comparison of the drawings of the planet made by different astronomers gives further confirmation of the difficulty of depicting the true character of the shadings which diversify the disk of Mars.

Right here I would like to recall the words of Dr. Campbell, Director of the Lick Observatory. After comparing the views of W. H. Pickering and Percival Lowell in parallel columns, he remarks,* "The really serious consideration is that the canals as observed by Pickering and the canals as observed by Lowell are just about as different as two observers could make them. . . . If two observers so advantageously situated, so capable and so enthusiastic as Pickering and Lowell can not agree better as to the basic observed facts of the Martian surface features, by virtue of studies extending through 27 and 23 years respectively what hope is there for ordinary observers to unravel the mysteries of the Martian canals? Is it possible that any one has been trying to see surface features on Mars which exceed the powers of existing telescopes and human eyes?"

If we had no means aside from telescopic observation of judging what the physical conditions on Mars really are, we should be as ignor-

*Publications A. S. P. Vol. XXX, page 146.

ant concerning them as Galileo was of the lunar surface when he viewed it through his first optic glass. It is well known that he supposed the dark areas on the moon to be seas; and we still retain the nomenclature which the astronomers of his time left to us. Fortunately there are other ways of learning about the physical state of the planets. The distance of a planet from the sun determines the amount of heat it receives. Upon the size of a planet and its gravitational pull depends the density and constitution of its atmosphere. Thus we learn that Mars receives less than half as much solar heat as the earth, and that it has probably not more than one-fourth as much atmosphere per unit of surface. Under these conditions the planet must naturally be extremely cold. Moulton finds a mean annual temperature of 39 degrees below zero, on the supposition that the surfaces of Mars and the earth radiate heat similarly. It is likely to be even lower on account of the rarity of the Martian atmosphere.

An attempt was made by Lowell some years ago to prove a higher temperature. This was based on the fact that the solar heat would penetrate to the surface of Mars much more readily than to the surface of the earth. This, of course, is true; but it is also true that the heat would be lost more rapidly. Assuming the constitution of the atmospheres to be similar, the conditions on Mars would be like those on a lofty mountain peak on the earth. The direct rays of the sun are very hot, but they do not melt the snow, which even in the tropics lasts the year round.

An excess of water vapor or an excess of carbon dioxide in the atmosphere would absorb the heat and raise the temperature of the planet. It is very doubtful whether water exists at all upon Mars, the surface gravitation of the planet not being sufficient probably to retain the particles of water vapor in the atmosphere. This was clearly proved by Professor Stoney in his "Memoir on the Atmospheres upon Planets and Satellites," published in the Scientific Transactions of the Royal Dublin Society, Vol. VI, pages 305 et seq. In this article he not only shows that water can not remain on Mars but that the polar caps are almost certainly formed by a deposit of carbon dioxide. I will quote briefly the conclusions which he draws.

"It appears here to be worth while reviewing the state of things that must prevail if the atmosphere of Mars consists mainly of nitrogen and carbon dioxide. Without water there can be no vegetation upon Mars, at least not such vegetation as we know; and in the absence of vegetation it is not likely that there is much free oxygen. * * * Carbon dioxide, the most condensible gas of such an atmosphere, would behave very differently from the way in which water behaves on the earth. Water in the state of vapor is so much lighter than the other constituents of the atmosphere that it hastens upward, and accordingly its condensation into cloud takes place usually at very sensible elevations. There would be no such hurry to rise; there would on the

contrary be great sluggishness in the diffusing of carbon dioxide through an atmosphere of nitrogen. When brought to the ground in the form of snow or frost, and when subsequently evaporated, the carbon dioxide gas would crawl along the surface, descending into valleys, occupying plains and pushing its way under the nitrogen, mixing only slightly with it. As a result only a very small proportion of the whole stock would be at any one time found elsewhere in the atmosphere than near the ground. It is suggested that the fogs, the snows, the frosts and the evaporation of such a constituent of the atmosphere may account for the peculiar and varying appearances upon Mars, which, though recorded on our maps as if they were definite, are in reality very imperfectly seen from our distant earth."

The absence of water vapor in the atmosphere of Mars is abundantly confirmed by spectroscopic observations. See especially the account of spectrograms obtained with high dispersion at the Lick Observatory (Publications of the A. S. P. Vol. XXII, pages 87 et seq.)

It may be claimed that an excess of carbon dioxide on Mars will raise the temperature. Owing to the escape of the lighter gases the proportion of carbon dioxide may well be somewhat greater on Mars than on the earth; but it should be noted that it is not the relative amount, but the total amount per unit of surface area that would influence the temperature. There seems no reason to suppose that this is appreciably greater in the case of Mars than of the earth. In any event this factor could not possibly raise the temperature 100 degrees Fahrenheit, which would be necessary to make the Martian conditions comparable to those of the earth.

The inclination of the equator to the orbit being practically the same for the earth and Mars, we should expect the annual range of temperature to be similar. The average temperature of the whole earth is about 60 degrees Fahrenheit. The avereage winter temperature of the arctic regions may be assumed as 20 degrees below zero. Taking the average Martian temperature as 40 degrees below zero, we should then have the average winter temperature around the poles 120 degrees below zero. Carbon dioxide solidifies at 109 degrees below zero. Therefore the natural explanation of the polar caps would be that they are composed of precipitated crystals of carbon dioxide. Indeed, this seems to be the only plausible explanation if we grant the absence of water.

We see then that a study of the physical conditions on Mars shows at once the absurdity of the popular views. Whatever the streaks on the planet's surface may be, they certainly are not canals. That seasonal changes take place is evident, but these probably have little in common with terrestrial changes. We must relegate Mars to the category of worlds long past their prime and already in the grip of approaching death.

Cincinnati Observatory, March 1922.

A SUGGESTION REGARDING GRAVITATION, II.

By WILLIAM H. PICKERING.

Since it may be a little puzzling to some people to read in my earlier paper (POPULAR ASTRONOMY, 1922, **30**, 155) that there is no attraction between a planet and the sun, and no centrifugal force engendered, when we all know that the planet circles around the sun in a closed orbit, it may be desirable to deal with this point a little more at length. Imagine a billiard ball *A* crossing a table with uniform velocity, and imagine it to be struck by ball *B*, so that both balls are deflected from their original courses. We should say that the change of direction experienced was due to the inertia of the balls, rather than to any centripetal or centrifugal forces coming into play. Suppose now that ball *A* is struck by ball *C*, and is again deflected.

If struck by a sufficient number of balls moving in the proper directions, and with the proper momentum, ball *A* might clearly be deflected into a circular course. It is believed that this is what the ether does to a planet, this action of the ether being due to the presence of the sun, as explained in detail in my first papr. It is hoped that this statement will make a little clearer how it is that there is no direct attraction between a planet and the sun, and no centrifugal force exhibited, such as occurs in the case of a restrained body, like a stone swung by a string. We thus see that it is an error to state that bodies attract one another across empty space, and we also find an additional reason, in spite of the Relativitists, to believe in the existence of the ether.

Menton, France, March 3, 1922.

"ASTRONOMY IMPROVED."

By CARL RUFUS.

A copy of "Astronomy Improved," by Nehemiah Strong, printed at New Haven in 1784, was obtained from the Library of Congress through the Interlibrary Loan. The title page (see illustration) indicates the nature of the contents. "Published for the Use, and at the Desire of the Students," it has been styled the first American textbook in astronomy. Limited to a special field of gravitational astronomy, the subject matter is presented in a systematic and thorough manner, illustrations and examples following analysis. The author adds at the end of Lecture II: "I have aimed at such an arrangement of thought, and methodizing of the subject, as I supposed most easy and natural; and though it be *new and different** from any I have ever yet met with, is yet wholly consistent with, and an *improvement** upon, the

*The italics are mine.

Aſtronomy Improved:

OR,

A NEW THEORY

OF THE HARMONIOUS REGULARITY OBSERVABLE

IN THE

MECHANISM OR MOVEMENTS OF THE

PLANETARY SYSTEM.

IN THREE LECTURES,

Read in the Chapel of YALE-COLLEGE, in NEW-HAVEN.
Begun February 17, 1781.

EXHIBITING

A NEW AND ACCURATE METHOD,

For inveſtigating the VELOCITIES, DISTANCES and PERIODS of the PLANETS; founded on the Nature of Gravitation, and Mathematical Relations and Dependencies between their Diſtances, Velocities and Periods: As alſo for finding the QUANTITIES of MATTER in the PRIMARY PLANETS; and the Figure of the MOON's ORBIT in open Space.

BY NEHEMIAH STRONG, M. A.
Profeſſor of Mathematics and Natural Philoſophy in that College.

Publiſhed for the Uſe, and at the Deſire of the Students.

Who hath comprehended the Duſt of the Earth in a Meaſure, and weighed the Mountains in Scales and the Hills in a Balance.
Prophet ISAIAH.

The Works of the LORD *are great, ſought out of all them that have Pleaſure therein.* PSALMIST.

NEW-HAVEN: *Printed by* Thomas & Samuel Green. 1784.

TITLE PAGE OF *"Astronomy Improved."*

same grand astronomical principles, which have hitherto obtained among the greatest masters of astronomy." This passage suggests the reason for adopting the title.

The author, Nehemiah Strong, (1729-1807) attended Yale, graduated in 1755, tutored and preached for several years, then became the first occupant of the new chair of Mathematics and Natural Philosophy

at Yale, a position which he filled creditably from 1770 to 1781, when he resigned on account of salary diffculty and turned his attention to law. He also prepared calculations for almanacs, an evidence at that time of profound erudition. He was called "a man of vigorous understanding." It was the course of astronomical lectures, however, delivered in Yale in 1781 and published in 1784, which gave him more than a passing reputation.

The treatise was dedicated "To the Reverend Ezra Stiles, D. D., President of Yale-College, and Professor of Ecclesiastical History in the same." It consisted of three lectures which we shall consider briefly. The title, Astronomy Improved, gives way to the page heading, Astronomical Lectures.

Lecture I has the caption: "Concerning the Nature and Operation of the Power of GRAVITATION and ATTRACTION—its Influence in regulating and adjusting the Motions, Periods, etc., of the PLANETS; with a new and ready method for investigating the same, etc." The purpose is clearly stated at the beginning: "I propose, in this Lecture, to entertain you with a Dissertation upon the subject of the Attraction of Gravitation, and the Laws relating thereto—and show its operation upon the Planets, and other bodies of the Solar System, in regulating and adjusting their Motions and Revolutions, Periodic Times, Velocities, Distances, etc., in respect of the Sun, their central body: As also the Mathematical Relation on which their *Velocities, Distances, Periodic Times,* and *Gravitations* toward the Sun, mutually bear to each other: Necessarily resulting from the very Nature of Attraction, and the Laws of Circular Motion."

The definition of gravitation given has scarcely been improved: "By Gravitation, we mean, that principle which taking place universally in all Material Substances, gives them a constant bias or *tendency* towards each other, by which they are inclined to come together if separate, or continue so when united."

A digression of several pages is evidently designed to ward off the attacks of ecclesiastical critics. The wisdom of this course may be appreciated by considering the Prince controversy with Winthrop of Harvard. Strong desired to support the orthodox belief in the immanence of God, so he contends that "this Universal Principle of Gravitation depends solely upon, or originates from an established ORDER or CONSTITUTION of the Supreme Author and Governor of the Universe; being constantly upholden and supported, by a certain regular and uniform agency of **GOD** himself, resulting from the simple and constant **FIAT** of his own meer volition." This recalls Herschel's definition, "Gravitation is the exerted will of God."

Returning to the subject the author considers the doctrine of gravitation from the standpoint of the "Quantity of Matter," emphasizing the fact that the attraction of two bodies is mutual, and stating the law that it is in exact proportion to the quantity of matter in each.

Then concerning distance (mass constant) he states that the actual force of attraction is inversely as the square of the distance. No symbols are used. The law of gravitation may be more precisely and clearly stated by the familiar formula

$$A = G \frac{m_1 m_2}{d^2}$$

where A, the attraction, is measured in force units, m_1 and m_2 are the masses of the two bodies, d is the distance between their centers and G is the constant of gravitation, believed to be a constant of nature, the numerical value of which depends upon the units of distance, mass and time employed. The author does not mention the name of Newton in connection with the law of gravitation. A similar omission may be noted concerning Kepler's third law relating distance and period of revolution. The only reference to authority is to Martin's Philosophy.

Proposition I is next considered. "The Quantity of Matter in the Central Body being supposed as given, or to be permanently the same; to find the Periodical Time by the Distance, and the Distance by the Periodical Time; applicable to the Sun and Primary Planets." The following principle is used; the periodical time must be in the compound ratio of the extent of the circle directly and of the velocity inversely. In the discussion and computations two auxiliary quantities are employed, tardity and levity, (see second illustration) which appear to be quite as important as period and distance. The following quotation will introduce these "articles." "It is well known, that the Levity, or diminution of Gravity, is directly as the square of the Planet's Distance from the Sun: Consequently, the Distance is the square root of the Levity. But it will be found that the decrease of *Velocity,* or the Tardity of Motion in Revolving Bodies, is always as the biquadrate root (the square root of the square root) of the Levity. Hence, should we assume any Comparative Distance of a Planet from the Sun, and square the same, this will give the Comparative Levity, or diminution of Gravity, in respect to that of another, to which it is compared: And the biquadrate root of that Comparative Levity will give the Comparative Tardity, or slowness of its Motion, in respect to the other." An illustrative problem is given. Assuming a planet whose distance from the sun is four times as great as the earth's, he finds that the geometrical series,—2, 4, 8, 16, represents the Comparative Tardity, Distance, Period and Levity. This may be taken to illustrate the remark: "There is an admirable consent and harmony subsisting between the Velocities, Distances, and Periodical Times, with the Power of Attraction, or their Gravitation towards their Central Body, at their respective Distances, even beyond what has ever as yet been treated of, by any astronomical writer whatever."

The author recognizes that Proposition I "depends upon this grand

and universal principle, that when we have the comparative distance of one planet in respect of another, of whatever number that comparative distance is the cube root, the square root of the same number will be the comparative time of its revolution." This is the Harmonic Law of Kepler, which does not take account of the masses of the planets.

ASTRONOMICAL LECTURES. 19

CASE I.

In which every Article is ſuppoſed ſeverally to be required.

1. TARDITY REQUIRED.

1 Found by extracting the Square-root of the *Diſtance.*
2 By extracting the Cube-root of the *Periodical Time.*
3 By extracting the Biquadrate-root of the Levity.
4 By dividing the Periodical Time by the *Diſtance.*
5 By dividing the Levity by the *Periodical Time.*

DISTANCE REQUIRED.

1 Found by ſquaring the *Tardity.*
2 By extracting the Square-root of the *Levity.*
3 By dividing the Periodical Time by the Tardity.
4 By extracting the Cube-root of the Square of the Periodical Time.

PERIODICAL TIME REQUIRED.

1 Found by cubing the *Tardity.*
2 By multiplying the Diſtance into the *Tardity.*
3 By extracting the Square-root of the Cube of the *Diſtance.*
4 By dividing the Levity by the Tardity.

LEVITY REQUIRED.

1 Found by involving the Tardity to the 4th Power.
2 By ſquaring the *Diſtance.*
3 By involving the Tardity into the *Periodical Time.*
4 By dividing the Rectangle of the Diſtance and Time, by the *Tardity.*

CASE II.

ILLUSTRATION II.

On page 19 (reproduced) to emphasize the "harmony," making five rules under each article, we propose to add: under Distance—5 By dividing the Levity by the Square of the Tardity; under Periodical Time—5 By extracting the Biquadrate Root of the Cube of the Levity;

under Levity—5 By extracting the Cube-root of the 4th Power of the Periodical Time. Of course the discerning reader may add other rules for mental amusement, e. g. Levity—6 By dividing the Square of the Periodical Time by the Distance.

Lecture II continues the same subject. At the beginning the question is proposed: "How long a time would a meteor, or any other revolving Body take in going round the Earth just above its surface; and with what Velocity must it move so as to go round the Earth in a true Circle, without falling to it, by the force of its own Gravitation, or the Earth's Attraction?" The distance of the moon is 240,000 miles and the meteor's distance (from the earth's center) is 1/60 of the moon's distance. The following quantities are found:

Tardity	Distance	Periodic Time	Levity
7.746	60	464.76	3600

"Here we see that the comparative time of the Moon's revolving, to that of the meteor, is 464.76; that is, the Moon's period is so much larger than that of the meteor: Hence if we divide 27 days, 7 hours, 43 minutes, the Moon's periodical time, by that number, we shall have 84 minutes and 39 seconds for the time required for the meteor to revolve round the earth at the proposed distance; and the velocity with which it moves, must be 7.746 times greater than that of the Moon in her orbit (as appears by the table above) which would be at the rate of 24½ miles in one second." There is evidently an error in the velocity which should be about 4.9 miles per second. The argument is correct, however, and the correct comparative value of the velocity is used in the interesting comment which follows: "This velocity is 17 times the velocity of the equatoreal part of the earth; so, if the earth's rotation increased 17 times, bodies at the equator would have no weight." 17 is the ratio of the earth's period of rotation to the meteor's period of revolution, so the velocity may not have been used.

Proposition II is presented next. "The Distance from the central Body being supposed to be given, or to be Permanently and Invariably the same, but the Quantity of Matter in the central Body, and the Periodical Times variable; to investigate the Quantity of Matter in the central, requisite to give a Motion to the revolving Body, that shall complete the Revolution, at the stated Distance, in any proposed Time: And also the reverse of this, viz. To investigate the Time requisite for a Body to complete its Revolution, at the stated Distance, answerable to any Quantity of Matter proposed for the central Body; or in other words, Supposing the Distance to be fixed and invariable, to find the Quantity of Matter in the central Body by the Time of revolving; or the Time by the Quantity of Matter in the central Body." This depends upon the universal principle: "That when the Distance of a revolving, from its central Body, is considered as permanently the same, the Quantity of Matter in the central Body must be directly as the Square of that Velocity required to carry it round in the pro-

posed time; or (which amounts to the same thing) inversely as the Square of the Time."

Proposition III again changes the constant. "The Periodical Time being permanently fixed, or the same, but the Quantity of Matter in the central Body, and the Distance of the revolving Body variable; to find the Quantity of Matter in the central, sufficient to carry the revolving Body round at any proposed Distance; and the reverse of this, To find a Distance answerable to any given or proposed Quantity of Matter in the central Body, at which the Body must revolve in the Stated Time." This depends upon the theorem: "The Quantities of Matter in central Bodies are in the direct Ratio of the comparative Cubes of the Distance of the revolving from the central Body, when the Periodical Times are given or permanently the same."

It will be noted that mass is constant in the first proposition, distance in the second, and period in the third; and of the two remaining quantities in each case, one is known or assumed, from which the other may be found. Applications of the propositions are made. Another interesting problem is solved. Given two bodies, the central body two inches in diameter and the revolving body one-tenth of an inch in diameter, with their centers one foot apart and densities equal to the mean density of the earth. Find the period of revolution. The result is 25 hours 29 minutes.

Lecture III contains remarks on the matters contained in the foregoing propositions. The first remark concerns the determination of Quantities of Matter in the Primary Planets, such as have secondaries. "For strange as it may seem to the unlearned, it is a real and demonstrable truth, that after knowing the Distances and Periodical Times of a Primary and its Secondary Planet, in regard of their respective central Bodies, we may really, and in a true philosophical sense, estimate, or as I may say, even weigh the Quantity of Matter in each; or at least, investigate the proportion which the Quantity of Matter in the one bears to that in the other." The use of the word, "weigh" was evidently designed to emphasize the sublimity and grandeur of the achievement by its association with the text of scripture quoted in this connection and printed on the title page.

The quantity of matter in the sun is found to be

4422.25 × Saturn.
1142.44 × Jupiter.
358062 × The Ea th.

Data were lacking for other determinations of mass. Uranus, discovered in 1781 by Herschel, did not disclose its two satellites, Oberon and Titania, until 1787.

The second remark of Lecture III pertains to the problem of finding a point between the earth and sun at which the moon would be equally attracted by the two bodies. The point is found to be 161,185 miles from the earth's center. As the actual mean distance of the

moon from the earth is 240,000 miles, at the time of new moon it is actually 78,815 miles nearer the sun than the determined point. This raises the question, why does the earth not lose its moon? The query is emphasized by the statement that at the critical point the sun's attraction for the moon is twice as great as the earth's attraction for it. The vividness of the question deserves a conclusive answer. Here it is. "When any system of Bodies, is by any means dislocated or disturbed; or, their situation, in respect of each other, altered, by an

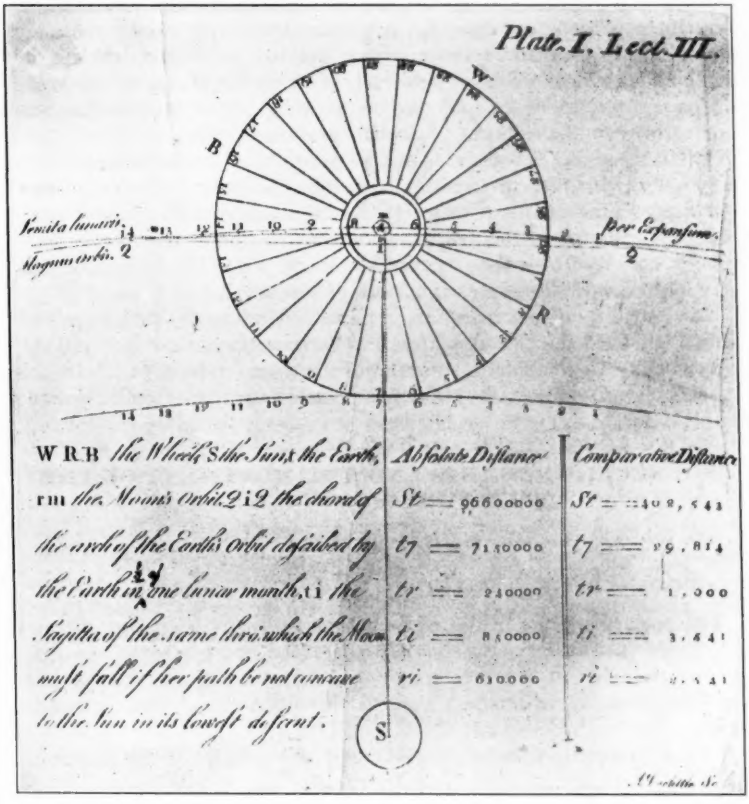

Platr. I. Lect. III.
W
B
R
Per Expansum
W R B the Wheel, S the Sun, the Earth,
r m the Moon's Orbit, 2 i 2 the chord of
the arch of the Earth's Orbit described by
the Earth in one Lunar month, i i the
Sagitta of the same Arch, which the Moon
must fall if her path be not concave
to the Sun in its lowest descent.
Absolute Distance
Comparative Distance
S

ILLUSTRATION III.

extraneous impulse common to them all, this does not essentially alter their motions in respect of themselves, so but that they will circulate as if there were no such impulse." Reference is also made to the mean relative distances, which must be taken into consideration.

An excellent piece of work follows, concerning the figure of the

moon's path, or more specifically: "The Figure of the Moon's Path or Track, as a concomitant of the Earth in its way round the Sun, in respect, not of the Earth, but of the Sun, or in absolute Space." Here the sun appears to be considered at rest in space. It will be recalled in this connection that Herschel's preliminary results on the sun's motion in space were published in 1783 and were accepted with some distrust by contemporary astronomers. Strong sets out to prove that in every part of its orbit the path of the moon is concave toward the sun; "so that in none of her Gyrations, round the Earth, does she ever describe any loops, by crossing her own track, or even form any Prominencies, toward the Sun, in her greatest excursions toward it; and could we have a fair view, of this Path of the Moon, in the Wide Expanse, or open Space, it would not sensibly differ from a true and even orbit round the Sun." (See illustration III).

The last subject discussed is the form of the orbits of the satellites of Jupiter with respect to absolute space (the sun). The two inner satellites describe paths consisting of arches connected by loops formed by the crossing of their own tracks. The two outer ones (only four were known) form arches without the loops. Plate II of the text, not here reproduced, illustrates this part of the work.

The entire treatise consists of 52 pages, including the title page and dedication, two additional plates herein mentioned, and a page of Corrigenda, which includes the author's apology: "Besides, there are lesser slips in pointing, etc. which the discerning reader will overlook with candor."

THE SECULAR COMETS AND THE MOVEMENT OF THE SUN THROUGH SPACE.*

By G. ARMELLINI.

Introduction.

The problem of the origin of comets has already been treated several times in this Review. I should therefore not return to the discussion if I did not desire to set forth a recent study of mine, and at the same time to make some observations upon the general methods employed in such questions.

In my preceding article, "Comets and the calculation of probabilities," I have examined synthetically the classical researches of Schiaparelli and Laplace, arriving at the conclusion that the theory of probabilities is powerless to solve the problem definitely.

After me, the distinquished Professor Strömgren has treated the question from another viewpoint; and we shall begin our study by examining the conclusions which he reached in his important article.

*From *Scientia*, September, 1921. Translated from the Italian by Prof. James P. Bird of Carleton College.

1. The Cometary Problem Examined with the Calculation of Perturbations.

The reader will remember that, according to Newton's Law, every body subjected only to the attraction of the sun, describes a conic having at its focus the sun itself. This conic then is an ellipse, a parabola, or a hyperbola, depending on whether its eccentricity is respectively less, equal, or greater than one.

Since the ellipse is a closed curve, while the other two are prolonged to infinity, it is clear that the problem of the origin of comets is closely connected with their eccentricity. But unfortunately, when a comet becomes visible, it is subjected not only to the sun's attraction, but also to that of the planets, and particularly to that of Jupiter. It therefore becomes necessary to free the observed eccentricity, from those alterations which are produced in it by these disturbing attractions, generally slight but complicated.

Several astronomers, Thraen, Fabry, Faye, and Strömgren, have worked out these most laborious calculations, arriving at the conclusion that the comets observed are probably all elliptical. Their appurtenance therefore to the solar system would seem to be proven; and any reader would, I believe, marvel upon seeing how Schiaparelli and Laplace have become lost in the thorny paths of the calculation of probabilities, instead of following this main road.

The truth is that traversing this road, the problem is not already solved but rather dismissed. This calculation in fact can be made only through a rather limited interval of time, since Celestial Mechanics has not yet sufficient means for determining in a general and rigorous way, the perturbations to which the orbit of a comet is subjected. Thus one might repeat in this connection the same words that Poincaré wrote regarding the stability of the planetary system: and that is that, notwithstanding the multitude of astronomical demonstrations, there might arise to-morrow a mathematician who would prove absolutely its instability!

For those readers who are not familiar with the mysteries of Celestial Mechanics, I think that here I may add some supplementary explanations.

2. How the Perturbations of Eccentricity are Calculated. Insufficiency of the Method.

The study of the trajectory described by a celestial body under the simultaneous attraction of the sun and the planets, is a problem which far surpasses the power of modern analysis. For comets this is rendered still more difficult because of the elongated form of their orbits, because of the large inclination to the ecliptic and, principally, because of their frequent passage near Jupiter or another planet. The astronomer is therefore constrained to abandon general calculations to follow little by little, the comet in its capricious course; as we

were saying, he must limit himself to calculating its special perturbations.

Let us suppose, for example, that today, the 15th of August, 1921, a comet had an eccentricity equal to 1.001. We wish to know what eccentricity it had for example, two years ago. The astronomer will begin by dividing this interval of time into many shorter intervals, generally of forty days each, and sometimes in the most difficult cases, even of twenty or ten days. Then he will ascertain what eccentricity and what other elements the comet had 40 days before the point of departure, namely the 6th of July, 1921. Having then executed this first numerical calculation, he will take as a basis the values obtained, and with these he will again go back to the 27th of May, 1921; and so on until he arrives at the determined limit.

But it is clear that however great may be the patience of the astronomers and their love for science, they will certainly not be able to go back to infinity by this most fatiguing ladder. Furthermore analysis proves that the more the calculation is prolonged, the more the exactness of the result is diminished. It is evident that this method will not give us any decisive answer to the problem that we may be treating. It will be able to tell us that a comet has been *inhabiting* the solar system for thirty or forty years, but we continue to be ignorant whether it was *born* there or came there from without.

Theoretically speaking, for example, the famous comet studied by Professor Strömgren, might possibly have come into the sphere of solar attraction twenty centuries ago, and its eccentricity might possibly have been subjected to slight oscillations, from more than, to less than unity, because of the attraction of the planets. No astronomer has ever been able to push his calculations of perturbations through an interval of twenty centuries, and on the other hand, some comets have an exceedingly long life. It seems certain therefore that the famous comet of Halley may have been seen by our forefathers some centuries before Jesus Christ. The hypothesis that we present is therefore at least theoretically possible.

It would be a mistake to believe, however, that the labors of the astronomers just named merit little consideration; they give us on the contrary a very weighty indication in favor of the solar origin of comets and they ought to be held in the highest esteem. Only let us repeat that a rigorous mathematical demonstration is not yet at hand. The calculation of perturbations, as that of probabilities, is in reality powerless to solve the difficult problem.

3. Periodical and Secular Comets.

There is, however, another indication in favor of the solar origin of comets, and to this, in so far as I know, no one has paid the attention it deserves. I believe it worth while therefore to set the matter before the readers of *Scientia*.

Let us suppose for a moment that it is possible to calculate exactly the planetary perturbations; and that the orbit of some comet, with these perturbations eliminated, turns out to be exactly parabolic or even slightly hyperbolic. All the books on astronomy will declare that such a comet ought certainly to be considered of stellar origin, and regard the fact as absolutely indisputable. This is a kind of axiom, which astronomers prefix to their dissertations regarding the cometary problem.

I desire on the other hand to show to my readers that the axiom is inexact, or at least not certain, since it rests, as we shall see, on data which are still rather doubtful. Accordingly I propose to show that a comet belonging to the solar system, might have a parabola or a hyperbola as its orbit, even after its eccentricity has had the planetary perturbations eliminated. However, such a comet will have an extremely long period, measurable in centuries rather than in years, and, for that reason, following the classical nomenclature of Celestial Mechanics, I shall give to these comets of exceedingly long period, the name of secular comets.

4. Research of the Author upon Secular Comets.

Let us take as usual the semiaxis of the earth's orbit as a unit, and let us remember that the nearest star, α Centauri, has a distance of about 300,000 units. Then come 21,185 Lalande and Sirius at a distance of about 500,000; then 36 Ophiuchi and 61 Cygni at a distance of 600,000 and so on. Nothing then prevents one supposing that there may exist periodic comets, belonging to the great solar family, which may reach a maximum distance (aphelion) of 100,000 or 150,000 astronomical units.

Exclusive of the particular case in which their movement is directed toward one of the few stars now being examined, they will describe their gigantic orbits around the sun, being slightly disturbed by the attraction of these single stars.[1] The author has however observed (and calculation justifies the observation) that their motion may be on the other hand notably influenced by the joint attraction of all the stars that surround the sun.

To examine the question in an elementary way let us remember that the galactic[2] concentration is rather weak for the stars visible to

[1]Apropos of this we remember the splendid work of Professor Burgatti, of the University of Bologna. Burgatti started with the hypothesis that a comet may come to us from a neighboring star, and from this he calculated the trajectory described under the simultaneous attraction of the sun and the star from which it comes, both supposed to be fixed in space. The study of the orbit is thus reduced to a classic problem of mechanics, and Professor Burgatti has deduced therefrom some very interesting results, particularly for the apparent distribution of the aphelia upon the celestial sphere. The reader desirous of further information may consult with profit this important work in the *Memorie dell' Accademia di Bologna.*

[2]The galactic concentration is the mean ratio between the apparent stellar density at 5 degrees galactic latitude, and that at 80 degrees.

the naked eye, that is, for the stars which are on the average nearest the sun. We may then suppose that the group of stars which surrounds the sun is nearly spherical and homogeneous, a hypothesis that is surely inexact, but valid for a first approximation. Then, as Rational Mechanics teaches, the sun S as well as the comet C will be subjected to an attractive force directed toward the centre O of the group and proportionately to their distance from O. The problem to be solved then may be formulated in the following manner:

"Two points S and C, (sun and comet) are mutually attracted according to Newton's Law. These are furthermore attracted toward a fixed point O, with a force proportionate to the distance. To find the trajectory that C describes around S."

The author has solved this problem and has calculated the orbit in question by means of some transcendental expressions which in mathematics are called elliptic functions. That which interests the astronomer is the following conclusion to which our calculation leads us.

Let us imagine a comet whose orbit, in the vicinity of the sun, is exactly parabolic or slightly hyperbolic, after the elimination of the planetary perturbations. According to common belief, this comet ought to move on the infinity; the calculation shows that the comet can not go beyond a certain limited distance. The joint attraction of the stars conspires therefore to hold back the comets in the vicinity of the sun; and similarly, this tends to prevent chance comets, belonging to other stars from escaping from them to come to us. There is thus a new argument in favor of the solar origin of comets.

But here is another still more curious result. The author has found that this limited distance is closely related to the time T which the sun employs in traversing its colossal orbit in space.

Leaving out the mathematical calculations, which the reader will be able to see in the "Memorie della Società Astronomica Italiana" and in the "Rendiconti dei Lincei," I shall limit myself merely to presenting a most simple formula. If we estimate T in years and measure the distance with the usual astronomical unit, my calculation shows that a comet exactly parabolic in the vicinity of the sun, reaches a maximum distance D given by the following equation:

$$D = (2\ T^2)^{1/3}$$

If, for example, we imagine that the sun traverses his orbit in ten million years, D will be equal to about 58,000. A comet of long period, whose maximum distance would be for example equal to 100,000 or 150,000, would appear therefore to us as hyperbolic, and that, notwithstanding the fact that the comet would belong entirely to the solar system. If we should put T equal to 40,000,000, D would then equal 147,000, and hence the parabolic or slightly hyperbolic comets would still belong to our sun. For T equal 200,000,000 we would then have D equal 470,000 and then, barring exceptional cases, the solar comets would have to be elliptical.

But, our readers will inquire, what is the duration T of a solar revolution? That we do not know! Astronomers speak, it is true, of fifty, one hundred, two hundred and fifty million years, but these are simply hypotheses. At most we shall be able to recall that fifty years ago the temperature of the solar photosphere was calculated at a million degrees; and A. Secchi himself, particularly competent in solar physics, warmly supported this opinion. Today on the other hand we know with certainty that it is less than ten thousand degrees. In our ignorance we ought for that reason to remember that the slight "hyperbolicity" of a comet, even though absolutely determined, should not suffice to prove its stellar origin.

And now, making a rapid synthesis of all that science tells us regarding our argument, we are able to arrive at the following:

5. Conclusions.

The methods employed in the study of the problem of comets may be classified in the following categories:

I. Classical methods, founded on the calculation of probabilities and developed with success by Laplace and Schiaparelli. I explained these in my first article, coming to the conclusion that comets can not proceed from those stars which have a perceptible movement with respect to the sun. The majority of the nearer stars are therefore excluded and hence the result is rather opposed to stellar origin.

II. Statistical Methods, studied by many astronomers and particularly by Prof. Leuschner. He has had the ingenious idea of comparing the percentage of parabolic orbits with the date of discovery and with the number of days during which the comets have been visible. His results are set forth in these two tables:

Table I.

Date of discovery	Parabolic Orbits
Prior to 1755	99%
1756-1845	74%
1846-1895	54%

Table II.

Visibility	Parabolic Orbits
1-99 days	68%
100-239 days	55%
240-511 days	13%

The result is thus opposed to stellar origin, since we see that the number of parabolic orbits keeps diminishing when the comets are observed for a long time and with more perfect instruments.

Some wise person has thus thought to present a new statistical argument by observing that if the comets did come from the stars, they should appear in larger numbers toward the apex, that is, toward that region of the sky toward which the sun is moving. It is clear in fact that if we were traversing a road where the air was thick with gnats,

that the larger part of the insects would come and stroke against the windshield, in front of the car, and not on the rear portions.

The argument seems rather attractive, and is even found repeated in many treatises on astronomy; but the author thinks that this is of no value. In fact, as we have seen, on the hypothesis of a stellar origin, the comets could come only from those stars which have no motion with respect to the sun. Relatively to these stars then the sun is at rest, and there can be no apex, or the opposite.

III. Method founded on the calculation of perturbations and developed by Fabry, Thraen, and Strömgren, who have set them forth clearly to the readers of this review in the articles cited. Although the result as we have now seen can not be regarded as final, it is however clearly opposed to stellar origin.

IV. Methods founded on stellar dynamics, of which the author has tried to give a rough draft in this article. These, as we have seen, strengthen the conclusions toward which the methods of the preceding groups tend. Let us suppose in fact, to face the worst hypothesis, that notwithstanding the researches of the astronomers already named, some one of the comets seems to have been really hyperbolic. That would not suffice to affirm with certainty its stellar origin, and therefore, since the enormous majority of comets observed belongs certainly to the planetary system, we have a right to believe that here belongs also this chance and exceptional comet. The result is therefore opposed to stellar origin.

Recapitulating, although no absolutely conclusive proof is yet known, all methods of investigation give results contrary to stellar origin. Quite rightfully then modern astronomy holds that comets are celestial bodies belonging strictly to the solar system, as if in homage to the old proverb: *moraliter certum ut absolute certum habetur.*

Padova, University.

THE PRESENT POSITION OF THE ISLAND UNIVERSE THEORY OF THE SPIRAL NEBULAE.

By DEAN B. McLAUGHLIN.

Our knowledge of the heavenly bodies may be said to vary inversely as their distances from us. The apparent motions of the bodies in the solar system were familiar to the ancients, but the stellar motions naturally remained unknown until long after the application of the telescope to observation. Although Roemer was the inventor of the transit instrument, it is probably fair to say that accurate knowledge of star positions begins with Bradley. As for the nebulae, they were not considered very important until the time of Sir William Herschel.

Observations of the brighter nebulae had been made long before

the time of Messier, but this persevering "comet ferret" discovered 66 previously unknown nebulae and clusters. His catalogue of 103 objects was published in the *Connaissance des Temps* for 1783 and 1784. Two of the objects are now known to be non-existent.

During the last twenty years of the eighteenth century, the great astronomer of Slough carried on a large part of his extensive researches, one of the important results being the discovery of about 2400 nebulae, twenty times as many as those previously known in the entire heavens. His son, John Herschel, discovered about 1700 in the southern hemisphere.

Kant had speculated on the subject of external galaxies, but we usually associate the name of Sir William Herschel with the island universe theory. He regarded the nebulae which he was unable to resolve into stars as extremely remote groups of stars which greater telescopic power might resolve. He thought them to be outside and independent of our galactic system,—complete galaxies in themselves. Later he concluded that some nebulae are gaseous, and he seems to have had some more or less definite notions concerning the formation of stars from nebulae.

Lord Rosse, using a speculum six feet in diameter, examined a great number of nebulae and thought that all of them showed signs of resolution. One of the objects which was "resolved" is the ring nebula in Lyra, and the Orion nebula nearly fell victim. But the business of "resolving" gaseous nebulae was stopped when Huggins found the spectrum of a planetary nebula to consist of bright lines, definitely proving its gaseous nature, and hence its irresolvability.

Unfortunately, too little distinction was recognized between the various types of nebulae. In those days a nebula was a nebula, and that was all that could be said. So we find all of these objects placed within the galactic system; the island universe theory sinks into the background.

Lord Rosse had detected the spiral form in a number of nebulae. That these bodies are truly of that form was proven by the photographs made by Sir Isaac Roberts with a twenty-inch reflector. Then followed the epoch-making work of Professor James Edward Keeler, using the Crossley reflector of the Lick Observatory. He stated as a conservative estimate that probably 120,000 nebulae were within reach of that instrument. A not less important discovery was the spiral character, not only of a score or two, but of the majority of the nebulae.[1]

The position of the spirals within the galactic system still remained unquestioned. Although they were observed to have continuous spectra they were not thought to consist of stars, but rather of continuous masses of gas under pressure. The most obvious fact in connection

[1]Keeler, J. E., Lick Obs. Pub. Vol. 8, p. 28.

with Keeler's discovery that many nebulae are spiral was this: ***the Laplacian type of nebula, long regarded as the progenitor of a solar system, was not found.*** The planetesimal hypothesis of Professors Chamberlin and Moulton regards the spiral nebulae as solar systems in the making.

The twentieth century has seen great advances made in nebular astronomy. It is becoming more and more evident that the spirals, whatever their nature, are enormous bodies at great distances from us. Their masses must be thousands of times that of the sun and their diameters are to be reckoned in light-years. They are far greater than was suspected at the time when the planetesimal hypothesis was formulated. Nevertheless, I believe that this is in no way detrimental to that view of the origin of the solar system.

As a consequence of this increasing certainty as to the vast sizes and distances of the spirals the old island universe theory of Herschel has been revived. The controversy on the subject is at its height at the present time; the evidence is contradictory. Some phenomena cannot be explained by any other theory than this; others seem to be of such a nature as definitely to disprove it.

At the risk of repetiton I will state the island universe theory in its present form. The galactic system in which the sun is situated, and which comprises all the visible stars, stellar clusters, and gaseous nebulae (except those in the Magellanic clouds) is only one of many such systems. These other systems are the spiral nebulae, comparable in extent with our own galaxy and situated at distances of hundreds of thousands or millions of light-years. Conversely, our galactic system is a spiral nebula.

Before entering upon a detailed discussion of this theory it would be well to bring together the observational facts which have been ascertained to date. As the problem of the constitution of the galaxy is intimately connected with the subject, it will be necessary to consider some data relating to the galactic system. Most of these facts are doubtless familiar, but it is very desirable that they all be brought together in a single place.

The Spirals.

Number.[2] They constitute the vast majority of the nebulae. It is now estimated that over 700,000 are within reach of the great reflectors.

Distribution.[3] They are most numerous about the galactic poles, the concentration about the northern being greater than about the southern. They are entirely absent from the Milky Way, but they approach it very closely in the Perseus region and they are sparse in

[2]Curtis, H. D., Lick Obs. Pub. Vol. 13, p. 14.
[3]Waters, S., Monthly Notices, Vol. 54, p. 526. 1894

the region between Crux and Sagittarius (the region of the globular clusters).[4]

Description. The form is a logarithmic spiral of two arms, lying sensibly in the same plane. There is a central condensation of lenticular form which frequently contains a sharp and more or less star-like nucleus. As the arms of the spiral wind outward they become more diffuse or more fragmentary, frequently consisting of chains of condensations or knots. In an area eight degrees in diameter about M 33, numerous small nebulae are found.[5] They appear to lie in the prolongations of the spiral arms. In many cases of spirals viewed edgewise we see a ring of occulting matter about the periphery.[6] Similar obscuring masses appear to lie between the spiral arms.

Proper Motion.[7] There is very little evidence on this point.

Radial Velocity.[8] The greatest velocities known. They are of the order of 1,000 km per second. The highest is that of N. G. C. 584, 1800 km per second. The majority of them are receding, but most of those observed are north of the galactic plane.

Rotation. N. G. C. 4594, an edgewise spiral, observed spectrographically, has a radial component of rotation of 330 km per second at 2′ from the nucleus.[9] Measures of direct photographs seem to indicate outward motion along the arms in M 101,[10] M 81, [11] M 33,[12] and M 51.[13] A period of rotation of 85,000 years is indicated for M 101.

Spectrum.[14] Appears like an integrated stellar spectrum. It is usually of approximately class F- G. In some cases bright nebular lines appear, and emission corresponding to that of class O or Wolf-Rayet stars is sometimes found.

Novae.[15] Temporary stars are of frequent occurrence in the spirals. Up to February, 1921, twenty novae had been observed in the Andromeda nebula alone. These are of about magnitude 17, with the exception of S Andromedae which reached the sixth at maximum. The decrease in brightness of these novae is similar in rate to that of galactic novae.[16]

In addition, an examination of spirals for polarized light gave negative or contradictory results.[17]

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[4]Shapley, H., Pub. Astr. Soc. Pacific, Vol. 30, p. 53. 1918.
[6]Curtis, H. D., Lick Obs. Pub., Vol. 13, pp. 45-54.
[5]Wolf, M., Veroeff. der Grossh. Sternwarte zu Heidelberg, Bd. 6. No. 10.
[7]Curtis, H. D., Pub. Astr. Soc. Pacific, Vol. 27, p. 214. 1915.
[8]Slipher, V. M., Popular Astronomy, Vol. 23, p. 23, 1915, Vol. 30. p. 11. 1922.
[9]Pease, F. G., Pub. Astr. Soc. Pacific, Vol. 28, p. 191. 1916.
[10]van Maanen, A., Astrophys. J., Vol. 44, pp. 210-228. 1916.
[11]Ibid., Vol. 54. pp. 347-356. 1921.
[12]van Maanen, A., Proceedings Nat. Acad. of Sciences, Vol. 7, pp 1-5. 1921.
[13]van Maanen, A., Astrophys. Jr., Vol 54, pp. 237-245. 1921.
[14]Fath, E. A., Astrophys. J., Vol. 37. pp. 198-203. 1913.
[15]Numerous notes in Pub. Astr. Soc. Pacific.
[16]Sanford, R. F., Pub. Astr. Soc. Pacific, Vol. 31, p. 109. 1919.
[17]Meyer, F. W., Lick Obs. Bull. 328. Reynolds, J. H., Monthly Notices, Vol. 72, p. 553. 1911.

The spiral arms are stronger in blue light than the nuclei.[18]

On the basis of probabilities the planes of an undue proportion of the apparently larger (and hence presumably nearer) spirals pass near the sun.[19]

The Globular Clusters.

Number. 108 are given in the New General Catalogue.[20]

Distribution. They are almost entirely confined to one hemisphere of the sky,[21] its pole being in the galactic plane in longitude 300°. This is the region of the sky most avoided by the spirals (see above under spirals).[4] Globular clusters are not to be found near the galactic equator,[22] although they otherwise show a concentration towards the Milky Way.

Proper Motion. None detected.

Radial Velocity.[23] Higher than that of any other class of objects save the spirals, being of the order of 300 or 400 km per second. Most of those observed are approaching.

Spectrum.[14] Resembles that of the spirals, being of classes F- G, but no bright lines have been noted as in the spirals. A great range of color index is found in the brighter stars of the clusters, thus indicating classes B- M. The brightest stars appear to be late-type rather than early-type.[24] Cepheid variables occur. Apparent magnitudes of stars are from about 11 down past the limit reached by the great reflectors.

The Galactic System Proper.

Some of the statements made under this head will not be the actual *facts* of observation, but will be inferences drawn from observational data and generally accepted.

Constitution and Structure. In the galactic system are included all the visible stars and coarse clusters. The globular clusters belong to it but we shall treat them as lying outside the system proper. All the gaseous nebulae, extended and planetary, (except possibly those in the Magellanic clouds) lie within its boundaries. It also contains dark nebulae, especially in the Ophiuchus region. The whole forms a discoidal body, or a very oblate spheroid, the diameter being about ten times the thickness. The Milky Way is partly an effect of looking through a much greater thickness of stars in that direction, but it is largely due to actual clouds of stars which form a rather complete ring around the whole.

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[18]Seares, F. H., Proceedings Nat. Acad. of Science, Vol. 2, p. 553. 1916.
[19]Reynolds, J. H., Monthly Notices Vol. 81, p. 130. 1920.
[20]Hinks, A. R., Monthly Notices, Vol. 71, p. 700. 1911.
[21]Ibid., p. 697. 1911.
[22]Shapley, H., Astrophys. J., Vol. 48, pp. 154-181. 1918.
[23]Slipher, V. M., Popular Astronomy, Vol. 26, p. 8. 1918. Ibid., Vol. 30, p. 11, 1922.
[24]Shapley, H., Astrophys. J., Vol. 49, p 41. 1919. See also proceedings Nat. Acad. of Sciences, Vol. 6, pp. 293-300. 1920.

Distribution.[25] The stars, clusters, and gaseous nebulae all show concentration towards the Milky Way. This is chiefly an effect of perspective. The planetary nebulae show a definite tendency to concentrate more closely towards the Milky Way in the region from Cepheus through Aquila to Argo, while they range farther from it in the other half. The coarse clusters show the same tendency.

Motions. There are two groups or streams of stars moving in opposite directions with reference to the centroid of the stars in the sun's neighborhood, but the motions of the fainter and more distant stars are unknown. The sun is not a member of either stream.

Novae in our system occur practically always in the direction of the Milky Way. The mean absolute magnitude of four galactic novae of known distance is —3.

The stars in the solar neighborhood are separated by distances of several light-years.

THE MAGELLANIC CLOUDS.

These resemble the Milky Way star clouds in general appearance, but it is thought that they show evidence of spiral structure. The greater cloud contains a number of gaseous nebulae, the lesser, but one.

Radial Velocity.[26] Greater + 276, Lesser + 168 km per second. Some of the nebulae used in obtaining these velocities are irregular gaseous nebulae. The bodies of this class in our galactic system are practically *at rest* with respect to the centroid of the stars in the solar neighborhood.

Objects which are otherwise confined to a small range on either side of the Milky Way occur in the clouds, e. g., coarse clusters, gaseous nebulae, class O stars. Globular clusters appear concentrated towards the clouds.[25]

The data given here are necessarily condensed, and full particulars can only be obtained from the original papers referred to.

Examining this observational material we see that the galactic system and the spirals have certain characteristics in common. Both are discoidal in form and are surrounded by rings or whorls irregularly condensed into knots. The convolutions of a spiral viewed from a point near the nucleus would present the appearance of the Milky Way. An integrated spectrum of the galaxy would show a strong resemblance to that of the spirals. There would be a predominance of solar type[27] with bright nebular lines from the extended nebulae, and possibly, but doubtfully, the bright lines characteristic of class O stars. Both the galactic system and the spirals contain great masses of occulting matter. It is especially noteworthy that novae, which are otherwise confined to the Milky Way, are of frequent occurrence in the spirals.

[25] Hinks, A. R., Monthly Notices Vol 71, pp. 693-698. 1911.
[26] Wilson, R. E., Lick Obs. Pub., Vol. 13, pp. 187-190.
[27] Fath, E. A., Astrophys. J., Vol. 36, pp. 362-367. 1912.

Whether the Magellanic clouds are themselves island universes or not, we can *call* them complete galaxies as a summary description, for they contain all the classes of bodies which are found in our galaxy. Their high radial velocities are very suggestive of some relation to the spirals, the more so as they are somewhat spiral in form. As a working hypothesis we might consider them to be very nearby spiral nebulae.

These first considerations are seen to favor the island universe theory, but we have hardly penetrated beneath the surface of the mass of facts. We shall now enter upon a detailed discussion of these facts and the inferences which can be drawn from them.

Considering first the distribution of the spirals, we notice that it is dependent on galactic latitude. A view which was long held may be called the relationship of avoidance: the fact that the spirals avoid the Milky Way was considered as conclusive proof that they are members of the galaxy. Recently, however, following the discovery of the dark nebulae, many have thought it more probable that absorption of light in passing through the greater depth of the galactic system cuts off all but the brightest of these bodies from our view. The adherents of the island universe theory point to the ring of occulting matter about the edgewise spirals and state that the absence of spirals from the Milky Way would be accounted for by the presence of a similar ring about the periphery of our system.[6] Whether the spirals are island universes or not, absorption would explain this feature of their distribution.

There are two other points which I believe have not been given the consideration which they deserve. The first of these is the strong tendency of the spirals to gather into clusters. The greatest of all these groups is situated in the constellation Virgo. Large and small spirals alike are clustered there. In the area between R.A. $12^h\ 9^m$ and $12^h\ 40^m$ and Decl. $+\ 12°$ and $+\ 19°$ are situated thirteen of the thirty-two spirals of Messier's catalogue. A glance at Mr. Sidney Waters' charts[3] will show the strength of this clustering power. The second point I have mentioned is the scarcity of spirals in the region of the clusters. I believe that this effect is real and not a result of the absorption of light. The strong concentration of the spirals into groups is obviously not an absorption effect, but I believe that the diminution of the numbers in the groups with increasing distance from the galactic pole may be due to the cutting off of the fainter spirals. This would hold true, of course, whether the spirals are island universes or not. Still, the falling off of their numbers as we leave the galactic pole is more rapid than we should expect if absorption alone is the cause.

Not only do the edgewise spirals show a peripheral ring of occulting matter, but the elliptical ones show dark "lanes" *at one extremity of the minor axis*. Now if these were really vacant spaces

they should be most prominent at the extremities of the *major axis* as Cassini's division in the rings of Saturn. Instead of attributing the absorption in edgewise and elliptical spirals to two causes, viz.: a peripheral ring and dark arms between the bright ones, I prefer to attribute both to the same cause:—the existence of a great quantity of dark matter on the outer edge of each spiral arm. This would explain both effects. The side of the nebula on which the "lanes" occur would then be the nearer side. Figure 1 is self-explanatory.

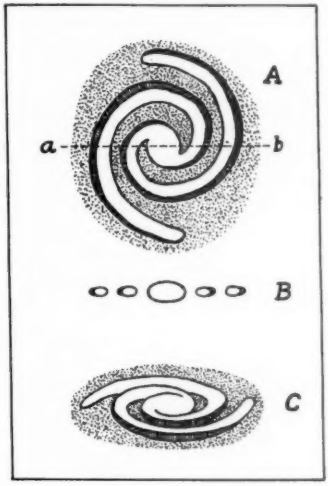

Fig. 1. The occulting matter in a spiral nebula. A, plan of spiral, B, cross section along line ab. C, perspective view. The shaded portion represents dark matter on the outer sides of the spiral arms; stippled represents the background of space.

When we consider the measures of rotation in the spirals we encounter the most contradictory portion of the evidence. The spectrographic measures require no comment; there is rotation in the spirals and its velocity is very high. Now a combination of the spectrographic velocities for edgewise spirals with displacements measured on direct photographs, taken at long intervals of time, of spirals which lie in planes perpendicular to the line of sight should give an approximate value of the parallax of a spiral. At the Mt. Wilson Observatory Mr. van Maanen has measured displacements on plates of four spirals taken at intervals of several years. Taking the case of M 101, if we assume a particle at 5′ from the center to pursue a circular orbit with a velocity of, say, 300 km per second, we get for the value of 1′, since the period of revolution is 85,000 years, 2.7 light-years, and the parallax is, roughly, 0.″0003, and the distance about 10,000 light-years. This would place the spirals close to the

outer borders of our galactic system. Let us now assume the spiral to be an island universe and let its diameter of 15′ (approximately) be equal to 30,000 light-years, the conventional estimate for the diameter of the galactic system. Then its distance would be 7,000,000 light-years, the circumference of the circular orbit would be over 63,000 light-years, and to complete the circuit in 85,000 years the particle would have to travel at three-quarters of the velocity of light! It is obvious that there is not the slightest hope of reconciling these measures with the island universe theory.

But the measures lead us still further; it is possible to compute the central mass under the attraction of which a particle would describe an orbit of semi-major axis 5′ with period 85,000 years. The expression is given by Mr. van Maanen:

$M = 0.0037$ (parallax in seconds of arc)$^{-3}$ (mass of sun), which is readily verified. Taking the parallax derived above, viz.: 0″.0003, we get for the mass, 140,000,000 suns. *This is one-seventh of the usual estimate of the mass of the entire galactic system!* Now is it possible that such tremendous masses can exist within such small distances of our galaxy and yet not have a profound influence on it? Galactic stars show no signs of such influence.

According to Professor Jeans' hypothesis[28] an outward motion along the spiral arms relative to the nucleus is what we are to expect. Briefly stated, his hypothesis starts with an enormous gaseous mass of great tenuity containing all the material of the galactic system. This was in rotation and when it had assumed a lenticular figure streams of gas were thrown off from two diametrically opposite points on the equator of the spheroid. These formed the arms of a spiral and broke up to form stars. The dispersal continued until the galactic system reached its present state of low star-density.

A difficulty lies in the fact that, on the basis of Jeans' hypothesis, after the visible spirals in our neighborhood have developed into galactic systems, assuming the parallax of the larger ones to be approximately the value derived from the measures of rotation, they cannot avoid overlapping and intermixing quite thoroughly. It is extremely improbable that our system should have escaped overlapping with others. This is, however, not contrary to Jeans' hypothesis, for if the spirals are island universes they are in a later stage of development than we should have to assume them if placed at small distances and consequently reduced in size.

By combining the radial velocities of the spirals with the very uncertain proper motions which have been observed we can state that about 10,000 light-years is a lower limit for their distances.

In the event of the truth of the island universe theory it is readily

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[28]Young, R. K. and Harper, W. E., Journal of the Roy. Astr. Soc. of Canada, Vol. 10, p. 134. 1916.

seen that the spectrum which is characteristic of the spirals is a natural consequence. But let us assume them to be at 10,000 light-years and determine what should be expected. We have calculated the mass and size of M 101 and, by making an assumption as to the thickness, we can calculate its density. We shall, of course, consider only the portion within a radius of 5′ of the center. The radius is 13.5 light-years and we shall assume a thickness of two light-years. The resulting value is 122,000 suns per cubic light-year, or one sun in a cube 1250 A.U. on a side. Now the mass of the sun if distributed throughout such a volume of space would be of cometary tenuity. Such a mass, if incandescent, would give a spectrum of bright lines. Hence, to give a continuous spectrum, it must be concentrated into a number of small bodies in which the gas will be under pressure. Now we know of no bodies much less massive than the sun which give a solar type spectrum. Professor Russell's very successful theory of stellar evolution has this postulate for one of its supports: that no body can attain the temperature of a given spectral type without having a certain minimum mass. If its mass falls below that figure it will only become, at its hottest, a star of later type.

It is evident that the spirals, if self-luminous, must be composed of stars or shine by light which is given off in a manner unknown to us. We might look at this consideration from the standpoint of surface brightness. If a spiral is a continuous mass of gas, and self-luminous, giving a solar type spectrum, it should have the surface brightness of a solar type star, which is obviously not the case.

If, then, the spirals are of stellar constitution, the stars are too faint for us to see or photograph with the largest of telescopes. At 10,000 light-years the sun, being of absolute magnitude 4.7 (the apparent magnitude as seen from a distance of 10 parsecs or 32.6 light-years) would appear as a star of magnitude 17. That the spirals are not composed of such stars is well known. For the sake of the argument let us make the improbable assumption that the stars of the spirals are only one-fortieth as bright as the sun, and therefore of the twenty-first magnitude. One million of them would make the spiral a sixth magnitude object, and only one spiral is of such great brightness. But we have computed the mass of the spiral to the 140,000,000 suns, hence, all but a fraction of one percent of the material in the nebula would have to be non-luminous or occulted.

(To be continued.)

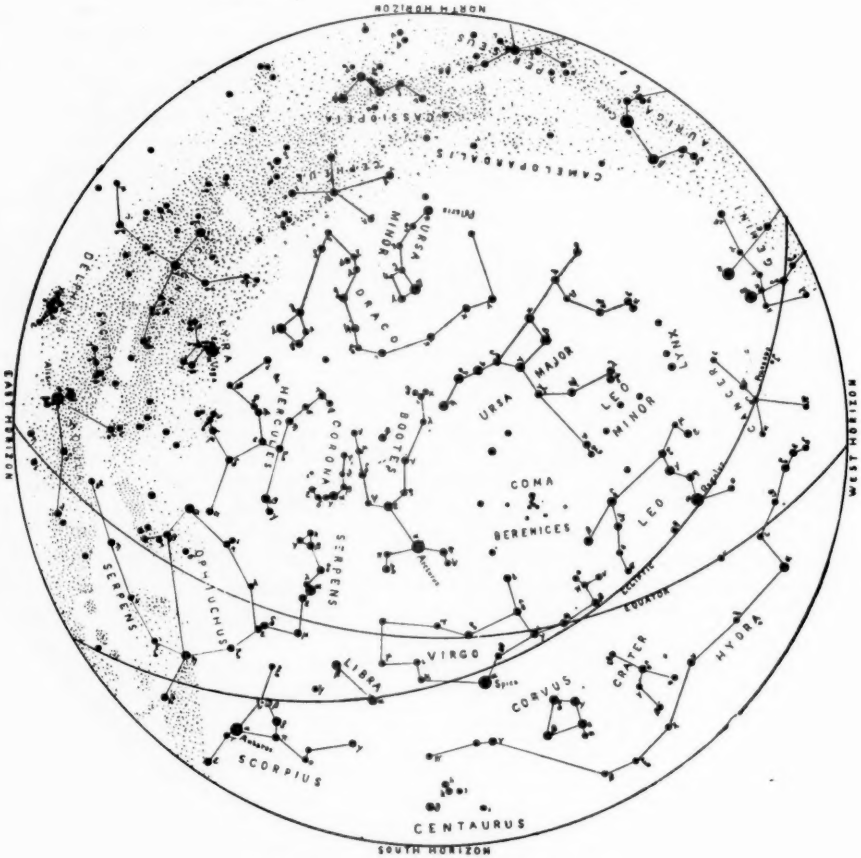
PLANET NOTES FOR JUNE.

(Central Standard Time.)

The *Sun* enters Cancer and summer begins at 11:27 P. M. on the 21st.

The phases of the *moon* will occur as follows:

	d	h	m	
First quarter	June 2	12	10.1	P. M.
Full moon	9	9	57.9	A. M.
Last quarter	17	6	3.2	A. M.
New Moon	24	10	19.7	P. M.



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1.

Mercury will reach its descending node at 4 A. M. on the 4th; aphelion on the 14th at 6 A. M. and inferior conjunction on the 18th at 3 A. M.

Venus will appear as the brightest star in the west after sunset. The planet will be close to Neptune at the end of the month, conjunction occurring at 2 A. M. July 1, with Venus 1° 44′ north of Neptune.

Mars reaches opposition on the 10th at 8 A. M. and will be nearest the earth on the 18th at 5 P. M. At this time its distance will be 42,300,000 miles. Even though comparatively close to the earth the planet will not be well situated for northern observers, as its declination will be 26° south. However, patient waiting at the eye end of a telescope may reward the observer with some good views of the planet's surface when atmospheric tremors cease at intervals.

Jupiter and *Saturn* will be in good position for observation in the early evening. On the 15th Saturn crosses the meridian at 6:34 P. M. and Jupiter about half an hour later. Saturn reaches quadrature on the 23rd at 4 A. M.

Uranus will be at quadrature on the 4th at 5 P. M. and therefore in position for observation for a short time before dawn. The planet's position on the 14th will be R. A. $23^h\ 00^m\ 44^s$, Dec. $-7°\ 10'\ 20''$.

Neptune passed quadrature early in May and will not be in good position for observation until after conjunction in August.

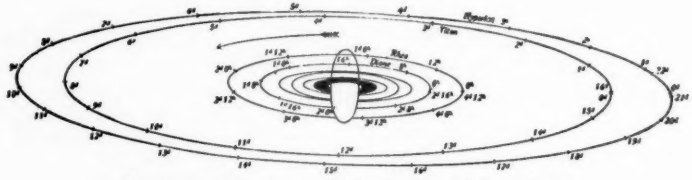
Phenomena of Jupiter's Satellites.

VISIBLE AT WASHINGTON.
[From the *American Ephemeris.*]
CENTRAL STANDARD TIME. NOON = 0^h

1922		h	m			1922		h	m		
June	2	9	58	I	Tr. I.	June	13	13	22	III	Ec. R.
		11	06	I	Sh. I.		14	12	03	II	Ec. R.
		12	06	I	Tr. E.		17	10	49	I	Oc. D.
		12	38	III	Tr. I.		18	8	10	I	Tr. I.
		13	16	I	Sh. E.			9	24	I	Sh. I.
	3	7	05	I	Oc. D.			10	22	I	Tr. E.
		10	25	I	Ec. R.			11	35	I	Sh. E.
	4	7	45	I	Sh. E.		19	8	43	I	Ec. R.
	5	9	26	II	Tr. I.		20	9	57	III	Oc. D.
		11	45	II	Sh. I.			12	25	III	Oc. R.
		12	01	II	Tr. E.		21	9	33	II	Oc. D.
	6	7	12	III	Ec. D.		23	8	46	II	Sh. E.
		9	24	III	Ec. R.		24	7	22	III	Sh. E.
	7	9	27	II	Ec. R.		25	10	04	I	Tr. I.
	9	11	50	I	Tr. I.			11	19	I	Sh. I.
		13	01	I	Sh. I.			12	16	I	Tr. E.
	10	8	56	I	Oc. D.		26	7	10	I	Oc. D.
		12	20	I	Ec. R.			10	38	I	Ec. R.
	11	7	29	I	Sh. I.		27	7	58	I	Sh. E.
		8	29	I	Tr. E.		28	12	07	II	Oc. D.
		9	40	I	Sh. E.		30	8	51	II	Sh. I.
	12	11	55	II	Tr. I.			8	52	II	Tr. E.
	13	8	34	III	Oc. D.			11	22	II	Sh. E.
		11	11	III	Ec. D.						

NOTE:—I. denotes ingress; E., egress; D., disappearance; R., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Saturn's Satellites.



Greatest elongations visible in the United States.
[From the *American Ephemeris.*]

CENTRAL STANDARD TIME. NOON = 0^h

I. Mimas. Period $0^d\ 22^h.6$.

1922	d	h		d	h		d	h		d	h
June	1	10.3 W	June	8	12.0 E	June	16	12.2 W	June	25	11.2 E
	2	8.9 W		9	10.6 E		17	10.9 W		26	9.8 E
	3	7.6 W		10	9.2 E		18	9.5 W		27	8.4 E
	6	14.7 E		11	7.8 E		19	8.1 W		28	7.0 E
	7	13.4 E		15	13.6 W		24	12.5 E			

II. Enceladus. Period $1^d\ 8^h.9$.

June	1	4.1 E	June	9	9.4 E	June	17	14.7 E	June	24	11.2 E
	2	12.9 E		10	18.3 E		18	23.6 E		25	20.2 E
	3	21.8 E		12	3.2 E		20	8.5 E		27	5.0 E
	5	6.7 E		13	12.0 E		21	17.4 E		28	13.9 E
	6	15.6 E		14	20.9 E		23	2.3 E		29	22.8 E
	8	0.5 E		16	5.8 E						

III. Tethys. Period $1^d\ 21^h.3$.

June	2	15.7 E	June	10	5.0 E	June	17	18.2 E	June	25	7.5 E
	4	13.0 E		12	2.3 E		19	15.5 E		27	4.8 E
	6	10.3 E		13	23.6 E		21	12.8 E		29	2.1 E
	8	7.6 E		15	20.9 E		23	10.2 E			

IV. Dione. Period $2^d\ 17^h.7$.

June	3	6.1 E	June	11	11.2 E	June	19	16.3 E	June	27	21.4 E
	5	23.8 E		14	4.9 E		22	10.0 E		30	15.1 E
	8	17.5 E		16	22.6 E		25	3.7 E			

V. Rhea. Period $4^d\ 12^h.5$.

June	1	15.3 E	June	10	16.2 E	June	19	17.0 E	June	28	18.0 E
	6	3.7 E		15	4.6 E		24	5.5 E			

VI. Titan. Period $15^d\ 23^h.3$.

June	1	16.2 W	June	9	18.2 E	June	17	15.0 W	June	25	17.3 E

VII. Hyperion. Period $21^d\ 7^h.6$.

May	30	9.6 W	June	11	9.6 E	June	20	13.9 W	July	2	14.7 E

VIII. Iapetus. Period $79^d\ 22^h.1$.

May	20	2.7 W	June	9	15.3 S	June	30	7.8 E			

IX. Phoebe. Period $523^d\ 15^h.6$.

		α Ph.—α Sat. m	α Ph.—α Sat. s	δ Ph.—δ Sat. ′	δ Ph.—δ Sat. ″			α Ph.—α Sat. m	α Ph.—α Sat. s	δ Ph.—δ Sat. ′	δ Ph.—δ Sat. ″
June	2	−1	32.1	+10	45	June	18	−1	12.8	+ 8	15
	4	−1	29.8	+10	27		20	−1	10.2	+ 7	55
	6	−1	27.5	+10	09		22	−1	07.6	+ 7	35
	8	−1	25.1	+ 9	50		24	−1	05.0	+ 7	15
	10	−1	22.7	+ 9	31		26	−1	02.4	+ 6	55
	12	−1	20.3	+ 9	12		28	−0	59.7	+ 6	34
	14	−1	17.8	+ 8	53		30	−0	57.0	+ 6	14
	16	−1	15.3	+ 8	34						

NOTE:—E, Eastern Elongation; I, Inferior Conjunction (south of planet); W, Western Elongation; S, Superior Conjunction (north of planet).

Occultations Visible at Washington.

[*From the American Ephemeris.*]

Date 1922	Star's Name	Magnitude	IMMERSION. Washington M.T.	IMMERSION. Angle from N	EMERSION. Washington M.T.	EMERSION. Angle from N	Duration
			h m	°	h m	°	h m
June 3	31 B. Virginis	6.4	8 05	187	8 31	227	0 27
6	μ Librae	5.4	9 13	177	9 46	225	0 33
12	27 G. Capriconi	6.2	14 00	43	15 19	284	1 19
17	44 Piscium	6.0	13 56	63	15 07	252	1 11
28	89 B. Leonis	6.2	7 56	132	8 51	268	0 55
28	π Leonis	4.9	9 02	150	9 43	248	0 41
30	9 B. Virginis	6.2	8 01	106	9 08	301	1 08

VARIABLE STARS.

Maximum of SS Aurigae 060547.—The following table of observations of the increase and the maximum light of the important irregular variable star SS Aurigae has been compiled by Mr. Campbell from measures made in December 1921 by members of the American Association of Variable Star Observers. The successful record of the rapid increase of light to an unpredicted maximum illustrates the high value of the coöperation of variable star observers widely distributed in longitude.

Julian Day	Magnitude	Longitude	Place	Observer
2423029.7	<13.7	72	Massachusetts	Young
3030.0	<13.9	224	Japan	Yamamoto
.22	<13.0	348	Italy	Lacchini
.32	12.8	349	Italy	Ginori
.37	12.3	336	Greece	J. Paraskévopoulos
.37	12.2	336	Greece	D. Paraskévopoulos
.5	11.9	84	Ohio	Peltier
.6	11.4	83	Florida	Bouton
.62	11.4	71	Massachusetts	Campbell
.68	11.3	348	Italy	Lacchini
.72	11.1	348	Italy	Lacchini
.75	10.9	78	Virginia	McCormick Observatory
3031.00	10.9	224	Japan	Yamamoto
.26	10.6	348	Italy	Lacchini
.4	11.0	349	Italy	Ginori
.41	10.8	355	Holland	Reesinck
.5	10.8	72	Connecticut	Olcott
.6	10.9	83	Florida	Bouton
.6	10.8	72	Massachusetts	Young
.6	10.8	74	New Jersey	Delmhorst
.63	10.8	71	Massachusetts	Campbell
.69	11.0	348	Italy	Lacchini
3032.22	11.0	348	Italy	Lacchini
.4	11.0	349	Italy	Ginori
.5	11.0	72	Connecticut	Olcott
.54	11.0	71	Massachusetts	Campbell

Harvard College Observatory Bulletin 766.

Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1922 June							
	h m	° ′		d h	d h		d h		d h		d h	
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8	1 6							
RT Sculptor.	31.5	—26 13	9.6—10.5	0 12.3	7 7		14 23		22 15		30 7	
UU Androm	38.5	+30 24	10.7—11.9	1 11.7	3 0		10 10		17 21		25 7	
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	5 14		13 1		20 13		28 0	
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	4 17		10 20		16 23		29 4	
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	5 12		12 16		19 19		26 23	
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	7 10		14 7		21 3		28 0	
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	3 18		10 23		18 3		25 7	
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	8 2		16 21		25 15			
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	1 0		8 23		16 21		24 20	
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6							24 23	
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	4 11		13 1		21 16		30 6	
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	4 12		11 7		18 2		24 21	
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9			8 12		16 10		24 7	
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5			9 6		17 13		25 20	
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	2 2		9 23		17 21		25 18	
RW Persei	13.3	+42 04	8.8—11.0	13 04.8	6 6				19 10			
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	7 18		17 4				26 15	
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	7 21				20 7			
TT Aurigæ	5 02.8	+39 27	7.8— 8.7	0 16.0	4 17		11 9		18 0		24 16	
RY Aurigæ	11.5	+38 13	10.7—11.7	2 17.5	6 7		14 12		22 16		30 20	
RZ Aurigæ	42.9	+31 40	10.6—13.3	3 00.3	6 15		18 16		24 17		30 17	
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	1 19		10 12		19 4		27 19	
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	2 9		12 19		23 5			
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2			8 10		16 10		24 11	
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	5 6		11 0		22 11		28 5	
U Columbæ	6 11.2	—33 03	9.2—10.0	2 19.2	5 0		10 15		16 5		27 10	
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	5 7		13 12		21 17		29 22	
RW Monoc	29.3	+ 8 54	9.0—10.8	1 21.7	2 6		9 21		17 12		25 3	
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	1 9		13 14				25 19	
RU Monoc.	6 49.4	— 7 28	9.8—10.5	0 21.5	1 10		8 14		15 18		30 3	
R Can. Maj.	7 14.9	—16 12	5.8— 6.4	1 03.3	1 12		15 3		21 22		28 18	
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2			8 7		17 14		26 22	
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	2 8		15 14		22 4		28 19	
TX Gemin.	30.3	+17 08	10.0—11.9	2 19.2	2 10		10 20		19 5		27 15	
RR Puppis	43.5	—41 08	9.4—10.7	6 10.3	1 10		14 7		20 17		27 3	
V Puppis	7 55.4	—48 58	4.1— 4.8	1 10.9	3 22		11 4		18 11		25 17	
X Carinae	8 29.1	—58 53	7.9— 8.7	0 13.0	7 23		16 2		24 5			
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	7 12		17 0				26 12	
RX Hydræ	9 00 8	— 7 52	9.1—10.5	2 06.8	1 20		15 12		22 8		29 5	
S Velorum	29.4	—44 46	7.8— 9.3	5 22.4	3 12		9 10		21 7		27 5	
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	1 3		7 21		21 9		28 3	
RR Velorum	10 17.8	—41 36	10.0—10.9	1 20.5	7 23		15 9		22 19		30 5	
SS Carinæ	10 54.2	—61 23	12.2—12.8	3 07.2	5 5		11 19		18 9		25 1	
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	3 19		12 14		21 10		30 5	
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	2 11		9 19		17 3		24 11	
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	1 11		8 6		21 20		28 15	
RZ Centauri	12 55.6	—64 05	8.5— 8.9	1 21.0	4 9		11 21		19 9		26 21	
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	8 2		17 17				27 7	
SS Centauri	07.2	—63 37	8.8—10.4	2 11.5	5 21		13 8		20 18		28 5	
133926 Hydræ	13 39.0	—26 23	8.6—12.7	2 21.5	5 10		11 5		22 19		28 14	

Minima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1922 June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
δ Libræ	14 55.6	— 8 07	4.8— 6.2	2 07.9	7 9	13 6	21 4	28 1				
U Coronæ	15 14.1	+32 01	7.6— 8.7	3 10.9	4 13	11 11	18 8	25 6				
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.3	2 21	11 7	19 17	28 3				
SS Librae	15 43.4	—15 14	9.3—11.5	0 18.4	8 12	16 3	25 19					
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	6 0	13 8	20 16	28 0				
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5		9 2	17 8	25 14				
R Aræ	31.1	—56 48	6.8— 7.9	4 10.2	5 17	14 14	23 10					
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1		11 9						
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	3 7	10 2	16 21	23 16				
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	5 9	13 19	22 4	30 13				
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	4 10	10 14	22 21	29 1				
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	4 14	16 22	23 3	29 7				
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	2 8	9 17	17 2	24 11				
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	1 10	9 15	17 19	25 23				
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	8 2	15 15	23 4	30 17				
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	2 0	9 17	17 14	25 5				
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	2 0	10 0	18 0	25 23				
WX Sagittarii	53.6	—17 24	9.2—10.8	2 03.1	4 2	12 14	21 3	29 15				
WY Sagittarii	17 54.9	—23 01	9.5—10.6	4 16.0		10 3	19 11	28 19				
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	5 13	15 22	26 6					
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	3 22	11 4	18 9	25 15				
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	2 19	9 17	16 14	30 10				
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	4 13		19 16					
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	6 8	13 12	20 16	27 20				
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	4 10	11 13	18 16	25 18				
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	1 4	9 11	17 19	26 2				
RR Draconis	40.8	+62 34	9.3—13	2 19.9	3 18	12 6	20 17	29 5				
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	4 14	11 6	24 13					
β Lyræ	46.4	+33 15	3.4— 4.1	12 21.8		13 2		26 0				
U Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	3 7	10 23	18 14	26 5				
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	2 11	10 1	17 14	25 4				
RV Lyræ	12.5	+32 15	11. —12.8	3 14.4	2 22	10 3	17 8	24 12				
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	6 0	14 23	23 21					
U Sagittæ	14.4	+19 26	6.5— 9.0	3 09.1	2 18	16 6	23 1	29 19				
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	1 15	9 0	16 9	23 18				
TT Lyræ	24.3	+41 30	9.4—11.6	5 05.8	3 16	14 4	19 9	29 21				
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	6 6	12 19	19 8	25 20				
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	3 21	15 22	21 22	27 22				
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	2 16	15 22	22 13	29 5				
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	1 20	9 23	19 3	28 6				
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	4 22	13 8	21 19	30 5				
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	6 2	12 21	19 16	26 11				
UW Cygni	19.6	+42 55	10.5—13	3 10.8	3 23	10 21	17 19	24 17				
V Vulpec.	32.3	+26 15	8.2— 9.8	37 19.0				27 15				
W Delphini	33.1	+17 56	9.4—12.1	4 19.4		9 19	19 10	29 1				
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	4 11	13 15	22 20					
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	2 17	10 5	17 16	25 4				
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	1 17	8 7	15 22	23 12				
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	1 11	10 14	20 16	30 19				
VVCygni	21 02.3	+45 23	12.1—13.8	1 11.4	2 8	9 17	17 2	24 11				
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3		9 15	19 8	29 1				
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	4 9	12 6	20 3	28 0				
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	2 15	12 19	22 22					
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3			19 10					
RW Lacertæ	22 40.6	+49 08	10.2—11.2	5 04.4	3 17	14 2	19 7	29 15				
8.1914 Pegasi	51.7	+32 41	10.0—10.6	5 06.4	3 22	9 4	24 23	30 6				
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.4	7 0	15 7	23 14					
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	3 14	11 3	18 15	26 4				
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	3 15	11 21	20 3	28 9				

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1922 June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7			8 14					
SY Cassiop.	0 09 8	+57 52	9.3— 9.9	4 01.7	4 1	12 16	20 20	28 23				
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3		8 4	15 22	23 16				
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2		13 7		28 3				
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 16	13 14	21 13	29 11				
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	2 9	10 4	17 23	25 18				
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	5 16	12 23	20 5	27 12				
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0		11		27				
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	2 2	10 15	19 5	27 19				
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1		11 7		22 11				
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0	4 5	15 20		27 11				
SX Aurigæ	5 04.6	+42 02	8.0— 8.7	1 12.8		8 3	15 18	23 10				
SY Aurigæ	05.5	+42 41	8.4— 9.5	10 03.3		10 3	20 6	30 10				
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	2 23	10 16	18 9	26 2				
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	6 9	17 11	22 21	28 12				
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	2 0	9 14	17 3	24 17				
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3		14 18						
RT Aurigæ	23.0	+30 33	5.1— 6.0	3 17.5	6 22	14 9	21 20	29 7				
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	1 12	15 22	23 3	30 7				
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	2 20	10 18	18 16	26 14				
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	5 1	15 4		25 8				
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	3 18			26 1				
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	5 16	13 15	21 13	29 12				
V Carinæ	8 26.7	—59 47	7.4— 8.1	6 16.7	8 21	15 14	22 7	28 23				
T Velorum	8 34.4	—47 01	7.6— 8.5	4 15.3		9 15	18 21	28 4				
V Velorum	9 19.2	—55 32	7.5— 8.2	4 08.9	6 17	15 11	24 5					
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0								
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	5 18	12 13	19 8	26 3				
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	4 13	17 18	24 9	30 23				
S Muscæ	12 07.4	—69 36	6.4— 7.3	9 15.8	2 16	12 8	21 23					
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7		8 16	16 15	24 15				
T Crucis	15.9	—61 44	6.8— 7.6	6 17.6	1 23	8 16	22 3	28 21				
R Crucis	18.1	—61 04	6.8— 7.9	5 19.8	5 7	11 3	22 19	28 14				
S Crucis	12 48.4	—57 53	6.5— 7.6	4 16.6	4 19	14 4	23 13	28 5				
W Virginis	13 20.9	— 2 52	8.7—10.4	17 06.5	3 2		20 8					
SS Hydræ	25.0	—23 08	7.4— 8.1	8 04.8	3 0	11 5	19 10	27 14				
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	5 8	12 9	19 9	26 10				
ST Virginis	14 22.5	— 0 27	10.3—11.4	0 09.9	3 16	11 21	20 2	28 7				
V Centauri	25.4	—56 27	6.4— 7.8	5 11.9	5 12	11 0	21 23	27 11				
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	2 2	9 15	17 4	24 17				
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	4 18	12 4	19 14	27 0				
R Triang. Austr.	15 10.8	—66 08	6.7— 7.4	3 09.3	4 5	10 23	17 18	24 13				
S Triang. Austr.	15 52.2	—63 29	6.4— 7.4	6 07.8	5 20	12 4	18 11	24 19				
S Normæ	16 10.6	—57 39	6.6— 7.6	9 18.1	5 19	15 13	25 7					
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	3 18	12 15	21 12	30 8				
RV Scorpii	16 51.8	—33 27	6.7— 7.4	6 01.5	4 0	16 3	22 5	28 6				
X Sagittarii	17 41.3	—27 48	4.4— 5.0	7 00.3	3 18	10 18	17 19	24 19				
Y Ophiuchi	47.3	— 6 07	6.1— 6.5	17 02.9	3 9		20 12					
W Sagittarii	17 58.6	—29 35	4.3— 5.1	7 14.3	4 14	12 4	19 18	27 9				
Y Sagittarii	18 15.5	—18 54	5.4— 6.2	5 18.6	5 10	11 5	22 18	28 13				
U Sagittarii	26.0	—19 12	6.5— 7.3	6 17.9	4 20	11 13	18 7	25 1				
Y Scuti	32.6	— 8 27	8.7— 9.2	10 08.3	2 9	12 17	23 1					
Y Lyræ	34.2	+43 52	11.3—12.3	0 12.1	4 4	16 5	22 6	28 7				
RZ Lyræ	18 39.9	+32 42	9.9—11.2	0 12.3	5 5	11 9	23 15	29 18				

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1922 June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
RT Scuti	18 44.1	−10 30	9.1— 9.7	0 11.9	6 20	12 19	24 16	30 15				
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	5 18	14 20	23 22					
U Aquilæ	19 24.0	— 7 15	6.2— 6.9	7 00.6	7 17	14 18	21 18	28 19				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	6 15	13 15	20 15	27 15				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	3 17	11 16	19 16	27 16				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	3 6	10 22	18 15	26 8				
η Aquilæ	47.4	+ 0 45	3.7— 4.5	7 04.2	3 6	10 10	17 15	24 19				
S Sagittæ	51.5	+16 22	5.6— 6.4	8 09.2		9 6	17 15	26 0				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	8 8	14 16	21 0	27 7				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3		11 2		27 11				
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	2 19	7 6	16 3	29 10				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	1 13	8 6	21 18	28 11				
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	2 16	16 2	22 20	29 12				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	7 3		21 20					
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	2 12	10 8	18 5	26 2				
SW Aquarii	10.2	— 0 20	9.9—10.8	0 11.0	1 1	7 22	21 17	28 14				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	3 20	13 13	23 7	28 3				
Y Lacertæ	22 05.2	+50 33	9.1— 9.6	4 07.8	6 20	15 11	24 3					
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	1 10	12 4	22 21	28 6				
Z Lacertæ	36.9	+56 18	8.2— 9.0	10 21.1	2 6	13 3	24 0					
RR Lacertæ	37.5	+55 55	8.5— 9.2	6 10.1	3 23	10 9	23 5	29 15				
V Lacertae	44.5	+55 48	8.5— 9.5	4 23.6	3 22	8 21	18 20	28 19				
X Lacertæ	22 45.0	+55 54	8.2— 8.6	5 10.7	1 18	7 5	18 2	29 0				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	5 3	16 0	21 11	26 21				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	1 13	14 4	20 11	26 18				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	1 13	13 7		25 20				
V Cephei	23 51.7	+82 38	6.0— 7.0	0 23.9	7 22	14 21	21 21	28 20				

New Variable Star in Pegasus.—Miss Harwood makes the following report concerning a new variable star found on photographs made at the Maria Mitchell Observatory at Nantucket:

The star in R. A. $22^h\ 53^m.9$, Dec. +14° 20′ (1900) varies from magnitude 12.0 to 12.6. It has been measured on five plates made on September 8, 1921, on which there are twenty-eight exposures covering an interval of 7.2 hours. In this time, apparently, the star completed one cycle of variation from maximum to maximum.

The range of variation has been verified on fifty-six photographs made at the Harvard College Observatory with the 8-inch Bache, 8-inch Draper, and the 16-inch Metcalf telescopes, between the years 1890 and 1916. The period is probably short or irregular.

Harvard College Observatory Bulletin 766.

COMET AND ASTEROID NOTES.

Eros and Palma.—Miss Margaret Harwood, Director of the Maria Mitchell Observatory, reports as follows concerning recent observations of asteroids:

Three series of photographs of Eros (433) were made at Nantucket during the nights of August 4, September 8, and October 2, 1921. The series consist

respectively of 14, 28, and 18 images, each of ten minutes exposure, and they cover intervals of 0.18, 0.30, and 0.17 days. There is only slight evidence of variation in brightness on any of these days; in fact, on September 8 Eros remained of nearly uniform magnitude, 12.0, for seven hours.

Observations of Eros on plates made at Arequipa in 1919 showed a variation of at least a magnitude in a period of about five hours.

From photographs taken on August 4, 1921, Palma (*372*) is suspected of varying four-tenths of a magnitude with a period of approximately one-tenth of a day.

Harvard College Observatory Bulletin 766.

Ephemeris of Encke's Comet.

Calculated by F. E. SEAGRAVE.

Gr. Midnight 1922	α h m s	δ ° ′ ″	Log r	Log Δ
April 15	22 32 58	—11 42 14	0.51108	0.57990
" 23	22 38 57	—11 4 22	0.51692	0.57335
May 1	22 44 5	—10 30 24	0.52252	0.56558
" 9	22 48 47	—10 0 58	0.52788	0.55666
" 17	22 52 29	— 9 36 24	0.53300	0.54672
" 25	22 55 17	— 9 17 21	0.53788	0.53586
June 2	22 57 5	— 9 4 19	0.54254	0.52424
" 10	22 57 47	— 8 57 49	0.54702	0.51216
" 18	22 57 20	— 8 58 16	0.55128	0.49981
" 26	22 55 39	— 9 5 55	0.55536	0.48757
July 4	22 52 40	— 9 20 59	0.55926	0.47588
" 12	22 48 38	— 9 40 43	0.56296	0.46526
" 20	22 42 52	—10 11 54	0.56650	0.45597
" 28	22 36 11	—10 46 15	0.56988	0.44887
Aug. 5	22 28 32	—11 24 37	0.57312	0.44439
" 13	22 20 13	—12 5 11	0.57620	0.44288
" 21	22 11 32	—12 45 55	0.57910	0.44458
" 29	22 2 52	—13 24 41	0.58188	0.44961
Sept. 6	21 54 37	—13 59 47	0.58452	0.45778
" 14	21 47 4	—14 29 49	0.58700	0.46872
" 22	21 41 3	—14 51 28	0.58938	0.48129
" 30	21 35 10	—15 11 49	0.59162	0.49715

Orbit of the Comet Brorsen-Metcalf.— In *Astronomische Nachrichten* No. 5144 Mr. P. Duckert, of Berlin-Charlottenburg, gives the results of an investigation of all the published observations of the periodic comet discovered by Brorsen in 1847, and found at its return after 72 years, in 1919, by Rev. Joel H. Metcalf. The identity of the two objects is established and the following sets of elements, referred to the ecliptic and equinox of 1925, are derived and represent the observations with a fair degree of accuracy:

Epoch of Osculation		1847 Sept. 9.5	1919 Sept. 22.5
Perihelion	T	1847 Sept. 9.602808 Berlin	1919 Oct. 16.881634 Gr.
Node to perihelion	ω	129° 25′ 20″.0	129° 30′ 57″.6
Node	☊	310 51 25.0	310 49 16.0
Inclination	i	19 07 38.0	19 11 34.9
	log q	9.688086	9.685666
	log e	9.987107	9.987305

Numbering of New Minor Planets.—In the *Astronomische Nachrichten*, No. 5153 is given the list of permanent numbers assigned to the asteroids which were discovered between August 1920 and April 1921. The number of asteroids which have received sufficient observation to determine their orbits is thus brought up to 950.

No.	Designation	Discoverer	Place	Date
934	1920 HK	Baade	Bergedorf	Aug. 15
935	1920 HM	Reinmuth	Königstuhl	Sept. 7
936	1920 HN	"	"	Sept. 8
937	1920 HO	"	"	Sept. 12
938	1920 HQ	"	"	Sept. 9
939	1920 HR	"	"	Oct. 4
940	1920 HT	"	"	Oct. 10
941	1920 HV	Palisa	Vienna	Oct. 10
942	1920 HW	Reinmuth, Schwassman	Königstuhl, Bergedorf	Oct. 11
943	1920 HX	Reinmuth	Königstuhl	Oct. 20
944	1920 HZ	Baade	Bergedorf	Oct. 31
945	1921 JB	Comas Solá	Barcelona	Feb. 3
946	1921 JC	Wolf	Königstuhl	Feb. 11
947	1921 JD	Schwassman	Bergedorf	Feb. 8
948	1921 JE	Reinmuth	Königstuhl	Mar. 3
949	1921 JK	Wolf	"	Mar. 11
950	1921 JP	Reinmuth	"	Apr. 1

Monthly Report of the American Association of Variable Star Observers, February 20 to March 20, 1921.

The present report owes much to the splendid lists of Messrs. Lacchini, Peltier, Bouton, and Waterfield. It will be noted that SS Aurigae passed a maximum early in March, and SS Cygni underwent another of its peculiar fluctuations just after reaching its maximum magnitude. All of the SS Cygni type stars repay careful watching. Mr. Lacchini has his new 5⅝-inch glass in use and Mr. Peltier is now using the Princeton 6-inch.

Mr. Julius F. Stone of Columbus, Ohio, and Dr. William Sturgis Bigelow of Boston, Mass., have been recently elected Patrons of the Association, the former for his generous contribution to the Pickering Memorial and the latter for his gift of a telescope, previously referred to.

The following have been recently elected to membership:

Paul Sprague, Claremont, Cal.
B. S. Hill, Yonkers, N. Y.
H. H. Coffel, Pennville, Ind.
O. W. Kennedy, W. Lafayette, Ind.
S. W. Johnson, Swarthmore, Pa.
W. Wetherbee, Albion, N. Y.
C. F. Johnson, Clinton, Conn.
R. N. Mayall, Framingham, Mass.
Dr. G. F. Swinnerton, Minneapolis, Minn.
Rev. W. G. Poor, Upton, Mass.
H. A. Macauley, Marshall, Minn.
W. Vokelek, Ludlow, Ky.
O. W. Persons, Minden, Neb.

The following observers contributed to this report: Messrs. Ancarani "An," Bouton "B," Brocchi "Br," Chandra "Ch," Miss Farnsworth "Fn," Ginori "Gi," Hunter "Hu," Jacobsen "Jb," Jewell "Je," Kanda "Kd," Lacchini "L," Leavenworth "Lv," Macaughey "Mc," Mrs. Morris "Ms," Dr. Paraskevopoulos "Jp," Mrs. Paraskevopoulos "Dp," Peltier "Pt," Pickering "Pi," Proctor "Pc," Reesinck "Rk," Skaggs "Sg," Townley "To," Vrooman "V," Waterfield "Wf," Watson "Pw," Yamamoto "Ym," and Miss Young "Y."

HOWARD O. EATON, Recording Secretary.

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922.

February 0 = J. D. 2423086 March 0 = J. D. 2423114

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
001046 X ANDROMEDAE—												
	3101.6	11.8	Lv,	3105.6	11.9	Wf,	3111.6	12.1	Lv,	3114.7	12.0	Wf,
	3124.7	12.6	Wf.									
001726 T ANDROMEDAE—												
	3093.6	12.5	Lv,	2101.6	12.8	Lv,	3107.1	11.0	Ch,	3111.6	12.8	Lv.
001755 T CASSIOPEIAE—												
	3100.4	8.4	Gi,	3106.3	8.2	An,	3106.6	8.1	Pt,	3106.8	8.3	L,
	3108.1	8.5	Ch,	3118.6	7.4	B.						
001838 R ANDROMEDAE—												
	3057.9	7.2	Ym,	3082.0	7.1	Ym,	3106.6	8.4	Pt,	3107.1	8.6	Ch.
001909 S CETI—												
	3090.2	8.5	L,	3108.1	8.5	Ch.						
003179 Y CEPHEI—												
	3120.5	12.0	B.									
004047 U CASSIOPEIAE—												
	3093.6	12.7	Lv,	3105.6	13.0	Wf,	3111.6	13.0	Lv,	3113.5	<12.6	Y,
	3114.7	14.1	Wf,	3124.7	<12.8	Wf.						
004435 V ANDROMEDAE—												
	3103.6	11.9	Lv,	3113.6	11.9	Lv.						
004533 RR ANDROMEDAE—												
	3105.6	8.9	Wf,	3114.7	9.1	Wf,	3115.6	9.7	B,	3124.7	9.8	Wf.
004746a RV CASSIOPEIAE—												
	3106.3	9.3	L,	3106.6	9.8	Pt,	3115.6	10.2	B,	3129.5	10.9	B.
004958 W CASSIOPEIAE—												
	3100.4	7.8	Gi,	3106.6	8.5	Pt,	3111.4	8.1	Rk,	3114.7	9.0	Br,
	3118.6	8.3	B.									
011208 S PISCIUM—												
	3111.5	<12.0	Fn.									
011272 S CASSIOPEIAE—												
	3093.4	8.8	Rk,	3103.6	9.6	Lv,	3105.7	9.4	Wf,	3106.6	9.6	Pt,
	3111.4	9.5	Rk,	3111.6	9.5	Lv,	3114.7	9.4	Wf,	3118.6	9.5	B,
	3124.7	9.4	Wf.									
011712 U PISCIUM—												
	3106.6	12.7	Pt.									
012350 RZ PERSEI—												
	3113.5	10.2	Y,	3129.5	10.0	B.						
012502 R PISCIUM—												
	3111.5	12.7	Fn,	3113.3	11.7	Rk.						
013238 RU ANDROMEDAE—												
	3105.6	10.8	Wf,	3106.6	11.0	Pt,	3107.1	10.6	Ch,	3114.7	10.8	Wf,
	3115.6	10.7	B,	3124.7	10.4	Wf.						
013338 Y ANDROMEDAE—												
	3107.1	<11.5	Ch.									
014958 X CASSIOPEIAE—												
	3062.0	11.0	Ym,	3106.6	10.9	Pt,	3115.6	10.1	B,	3129.5	10.1	B.
015354 U PERSEI—												
	3106.6	7.8	Pt,	3118.6	8.2	B.						
021024 R ARIETIS												
	3090.3	12.6	L,	3100.3	12.1	Gi,	3105.7	11.6	Br,	3109.3	11.5	L,
	3110.6	11.5	B,	3112.4	10.8	Gi,	3122.6	10.4	B.			
021143a W ANDROMEDAE—												
	3090.3	11.8	Gi,	3105.6	12.6	Wf,	3112.4	12.4	Gi,	3114.6	13.4	B,
	3114.7	12.8	Wf.									
021403 o CETI—												
	3058.0	9.3	Ym,	3088.2	9.2	An,	3088.3	9.1	L,	3089.7	8.8	Jb,
	3090.3	8.9	An,	3090.3	9.1	L,	3097.7	8.8	Jb,	3100.3	9.0	L,
	3106.3	8.6	L,	3107.1	8.5	Ch,	3109.2	8.4	L,	3109.2	8.3	An,
	3112.3	7.8	L,	3129.5	6.2	Pt.						

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
021558 S PERSEI—												
	3115.6	9.6	B,	3129.6	9.4	B.						
022000 R CETI—												
	3080.9	10.5	Kd,	3085.0	10.8	Kd.						
022150 RR PERSEI—												
	3110.6	9.7	Fn,	3114.6	9.0	B,	3129.5	9.7	Pt,	3129.6	9.1	B,
	3131.5	9.8	Y.									
022813 U CETI—												
	3058.0	11.7	Ym,	3107.1	8.1	Ch,	3111.5	7.5	Fn.			
022980 RR CEPHEI—												
	3105.7	14.2	Wf,	3109.4	14.1	L,	3114.7	14.2	Wf.			
023133 R TRIANGULI—												
	3080.9	6.7	Kd,	3085.0	6.7	Kd,	3086.9	7.1	Kd,	3089.9	7.3	Kd,
	3095.9	7.3	Kd,	3105.0	7.6	Kd,	3106.6	7.0	Pt,	3111.4	7.4	Rk,
	3120.6	8.3	B.									
024356 W PERSEI—												
	3056.0	8.8	Ym,	3057.9	9.0	Ym,	3058.9	8.6	Ym,	3061.0	9.0	Ym,
	3061.9	9.1	Ym,	3062.9	8.9	Ym,	3065.0	8.9	Ym,	3065.9	8.7	Ym,
	3075.9	8.8	Ym,	3079.0	8.9	Ym,	3081.9	9.1	Ym,	3088.7	8.8	Jb,
	3089.7	9.0	Jb,	3090.9	8.9	Ym,	3097.6	8.8	Jb,	3105.7	8.5	Br,
	3106.6	8.7	Pt,	3111.0	8.6	Ym,	3113.7	8.8	Jb,	3114.7	9.0	Br,
	3115.6	8.6	B,	3117.5	8.9	Pi,	3129.6	8.6	B.			
030514 U ARIETIS—												
	3100.3	13.8	Gi,	3112.4	13.4	Gi,	3131.5	12.0	Y.			
031401 X CETI—												
	3088.2	9.0	L,	3105.7	8.8	Wf,	3106.6	8.9	Pt,	3109.3	9.3	L,
	3114.6	8.7	Wf,	3124.7	8.9	Wf.						
032043 Y PERSEI—												
	3052.9	8.5	Ym,	3075.9	8.5	Ym,	3106.6	9.6	Pt,	3115.6	9.7	B.
032335 R PERSEI—												
	3100.4	8.8	Gi,	3106.6	8.1	Pt,	3112.4	8.9	Gi,	3115.6	8.9	B,
	3117.5	8.7	Pi,	3129.6	9.3	B,	3130.6	9.2	Hu.			
041619 T TAURI—												
	3088.3	9.4	Jp,	3088.3	9.4	Dp,	3090.3	10.0	Dp,	3100.3	10.3	Jp,
	3104.2	9.7	Jp,	3104.2	9.8	Dp.						
042209 R TAURI—												
	3114.6	13.5	B.									
042215 W TAURI—												
	3100.3	9.7	Jp,	3104.2	10.2	Jp,	3104.2	10.2	Dp,	3105.4	10.4	Je,
	3105.7	10.3	Br,	3106.6	10.6	Pt,	3106.7	10.0	Sg,	3111.4	10.4	Je,
	3111.6	10.6	V,	3113.7	10.4	Sg,	3113.7	10.2	Jb,	3114.6	10.3	B,
	3116.4	10.4	Je,	3117.7	10.4	Sg,	3122.7	10.3	Sg,	3125.6	11.0	B,
	3125.7	10.4	Sg,	3130.5	11.0	Pi,	3130.6	10.9	Hu.			
042309 S TAURI—												
	3114.6<	13.8	B.									
043065 T CAMELOPARDALIS—												
	3090.3	12.5	L,	3106.4	11.4	L,	3129.5	9.2	Pt.			
043208 RX TAURI—												
	3114.6	12.9	B,	3129.6	12.3	B.						
043274 X CAMELOPARDALIS—												
	3108.7	8.0	Pt,	3109.2	8.6	Ch,	3110.6	8.4	Fn,	3111.4	8.5	Rk,
	3114.7	8.6	B,	3127.6	9.5	B.	3130.6	10.0	Hu.			
044617 V TAURI—												
	3094.6	11.1	B,	3104.3	12.1	Jp,	3104.3	12.0	Dp,	3106.6	11.8	Pt,
	3114.6	12.6	B.									
045221 U LEPORIS—												
	3082.0	10.5	Ym,	3104.3	11.2	Dp,	3104.3	11.0	Jp.			
045307 R ORIONIS—												
	3102.3	12.9	Gi,	3107.6	13.0	B.						

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
045514 R LEPORIS—												
	3082.0	10.0	Ym,	3087.4	8.9	Rk,	3090.3	10.4	L,	3102.4	8 9	Rk,
	3105.7	9.9	Br,	3106.4	10.2	L,	3106.6	10.6	Pt,	3108.2	10 5	Ch,
	3110.7	9.0	B,	3112.3	9.1	L,	3117.6	9.5	Je,	3122.6	8.9	B.
050003 V ORIONIS—												
	3106.6	10.6	Pt,	3110.7	11.5	B,	3123.6	12.1	B.			
050022 T LEPORIS—												
	3082.0	8.4	Ym,	3106.6	8.3	Pt,	3114.6	8.4	B.	3127.6	8.2	B.
050923 R AURIGAE—												
	3103.6	12.9	Lv,	3105.7	<11.4	Br,	3106.6	12.8	Pt,	3111.6	13.0	Lv,
	3113.6	13.0	Lv,	3117.6	12.9	Je,	3119.6	12.6	Je.			
052034 S AURIGAE—												
	3090.3	10.2	L,	3111 3	10.0	L,	3114.7	9.5	B,	3129.6	10.3	Pt,
	3129.6	9.4	B,	3130.5	10.4	Pi.						
052036 W AURIGAE—												
	3102.4	13.2	Gi,	3109.4	13.0	L,	3112.3	12.5	L,	3112.4	12.6	Gi,
	3117.5	11.9	Pi.									
052404 S ORIONIS—												
	3107.6	13.2	B.									
053005a T ORIONIS—												
	3047.4	10.7	Jp,	3088.2	10.6	An,	3088.3	10.8	L,	3090.3	9 9	An,
	3090.3	9.9	L,	3100.3	10.2	L,	3106.4	9.9	An,	3106.4	10.6	L,
	3106.6	10 6	Pt,	3109.3	10.4	An,	3109.3	10.5	L,	3110.6	10.2	Pt,
	3111.3	10.2	L,	3112.3	10.1	L,	3112 3	10.0	An,	3114.6	9.9	B,
	3117.5	10.2	Pt,	3122.6	10.0	Pt,	3125.6	11.2	B,	3129.6	10 6	Pt,
	3130.6	10.9	Hu.									
053068 S CAMELOPARDALIS—												
	3108.7	8.8	Pt.									
053326 RR TAURI—												
	3107.7	11.8	B,	3122.6	<12 2	B,	3129.6	<12.8	B.			
053531 U AURIGAE—												
	3114.6	13.1	B,	3125.6	<12.5	B,	3131.7	12.8	Y.			
054319 SU TAURI—												
	3044.4	9.4	Jp,	3047.4	9.3	Jp,	3062.0	9.5	Ym,	3070.9	9.5	Ym,
	3084.9	9.5	Ym,	3088.3	9.3	L,	3088.4	9.5	Dp,	3088.4	9.4	Jp,
	3090.4	9.5	Rk,	3090.4	9.4	L,	3090.4	9.3	An,	3100.3	9.5	L,
	3105.6	9.4	Br,	3105.6	9.2	Je,	3105.7	9.4	Wf,	3106.4	9.6	L,
	3106.6	9.5	Pt,	3106.7	9.4	Wf,	3107.7	9.5	B,	3107.7	9.4	Wf,
	3108.2	9.7	Ch,	3108.6	9.4	Wf,	3108.6	9.6	Pt,	3109.4	9.6	An,
	3109.7	9.4	Wf,	3110.6	9.1	Fn,	3110.7	9.4	Wf,	3111.0	9.4	Ym,
	3111.3	9.4	L,	3111.4	9.5	Rk,	3111.6	9.0	V,	3111.7	9.4	Wf,
	3111.7	9 2	Br,	3111.8	9.6	Pt,	3112.3	9.4	L,	3112.4	9.6	An,
	3112.7	9.4	Wf,	3113.7	9.5	B,	3113.7	9.5	Wf,	3114.7	9.4	Wf,
	3115.7	9.4	Wf,	3116.5	9.4	Pt,	3117.5	9.4	Pt,	3117.6	9.6	Pc,
	3118.6	9.7	Je,	3118.7	9.4	Wf,	3119.7	9.4	Wf,	3119.8	9.6	Pt,
	3122.6	9 6	Pt,	3125.6	9.2	Je,	3125.6	9.5	Pc,	3125.6	9.5	B,
	3125.7	9.6	Pt,	3127.6	9.5	B,	3129.6	9.6	Pt,	3130.5	9.4	Pi,
	3130.6	9.7	Pt,	3131.6	9.8	Pc.						
054615a Z TAURI—												
	3117.5	11.6	Fn.									
054615c RU TAURI—												
	3117.5	10.6	Fn.									
054920a U ORIONIS—												
	3062.0	10.1	Ym,	3075.9	10.8	Ym,	3082.0	11.6	Ym,	3084.9	11.6	Ym,
	3090 9	11.9	Ym,	3101.6	11.8	Lv,	3105.7	11.6	Je,	3108.2	11.8	Ch,
	3108.7	12.0	Pt,	3110.6	12.0	B,	3111.0	12.4	Ym,	3111.6	12.0	Lv,
	3111.6	12.4	Je,	3113.7	12.5	Jb,	3116.6	12 2	Je,	3118.6	12.2	Je.
	3130.6	12.0	Hu.									
054920b UW ORIONIS—												
	3101.6	10.7	Lv,	3111.6	10.5	Lv.						

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
054974 V CAMELOPARDALIS—												
	3106.4	13.6	Gi,	3107.7	13.6	B.						
055353 Z AURIGAE—												
	3105.7	10.9	Br,	3105.7	10.8	Wf,	3107.7	10.5	B,	3108 7	10.3	Pt,
	3114.7	10.5	Wf,	3117.5	10.7	Pi.	3119.8	10.4	Wf.			
060450 X AURIGAE—												
	3108.7	9.5	Pt,	3109.2	8.9	Ch,	3110.6	9.2	B,	3122.5	8.4	Mc,
	3130.6	8.7	Hu.									
060547 SS AURIGAE—												
	3044.4<13.0		Jp,	3047.4<13.0		Jp,	3088.4<13.0		Jp,	3088.4<13.0		Dp,
	3056.0<13.9		Ym,	3057.0<13.9		Ym,	3057.9<13.9		Ym,	3059.0<13.9		Ym,
	3061.0<13.9		Ym,	3061.9<13.9		Ym,	3062.9<13.3		Ym,	3064.9<13.3		Ym,
	3065 9<12.4		Ym,	3075.9<13.9		Ym,	3079.0	10.8	Ym,	3082 0	12.0	Ym,
	3084.9<13.7		Ym,	3087.4<11.0		Rk,	3090.3<13.9		Gi,	3090.4<11.8		Rk,
	3090.9<13.9		Ym,	3093.4<11.8		Rk,	3095.4<11.0		Rk,	3097.4<11.0		Rk,
	3100 3	13.9	Gi,	3100.4<12.4		L,	3102.3	13.9	Gi,	3102.4<12.4		Rk,
	3105.6<11.6		Br,	3106.3<13.6		L,	3106.3	13.9	Gi,	3106 6<12.6		Pt,
	3107.4<12.4		Rk,	3108.6<12.6		Pt,	3109.3	13.9	Gi,	3109.4<14.5		L,
	3109.2<11.8		Ch,	3110 6<12.4		L,	3111.0<13.9		Ym,	3111.4<14.5		L,
	3111.4<12.4		Rk,	3111.4	13.9	Gi,	3111.6<11.2		V,	3111.6<13.3		Fn,
	3111.7<11.8		Br,	3111.8<12.6		Pt,	3112.4	13.9	Gi.	3112 4<14.5		L,
	3113 3<12.4		Rk,	3113.7<14.0		B,	3114.3<12.4		L,	3116.7<10.8		Je,
	3117.5<11.4		Pi,	3117.6	12.4	Pc,	3118.7<10.8		Je,	3118.8	10.9	Pt,
	3119.8<10.8		Je.	3119.8	10.0	Pt.	3120.6	10.9	Y.	3122.6	10.8	Fn.
	3122 6	10.9	Pt,	3125.6	11.1	Pc.	3125.6	11.0	B,	3126.6	11.2	B,
	3127.6	11.7	B.	3128.5	12.2	B.	3129.6	12.5	B,	3129.6	13.0	Pt,
	3130.5<12.4		Pi.	3130.6<12.6		Pt.	3131.6	13.7	Pc.	3131.7<13.0		Y.
060124 S LEPORIS—												
	3082.0	5.9	Ym.									
061647 V AURIGAE—												
	3107.7	12.6	B,	3113.7	12.5	B.						
061702 V MONOCEROTIS—												
	3129.6	11.9	Pt.									
063159 U LYNCIS—												
	3111.6<13.1		Fn,	3130.5<12.4		Pt.						
063308 R MONOCEROTIS—												
	3113.7	11.6	B,	3129.6	11.0	Pt.						
063558 S LYNCIS—												
	3105.6<11.7		Br,	3130.5<12.6		Pi.						
064030 X GEMINORUM—												
	3102.4	11.8	Gi,	3102.6	12.2	B,	3130.5	10.4	Pi.			
064707 W MONOCEROTIS—												
	3107.7	9.5	B,	3108.7	10.5	Pt.	3113.6	9.5	B,	3125.6	9.4	B.
064932 NOVA GEMINORUM #2—												
	3109.3	14.0	L.									
065111 Y MONOCEROTIS—												
	3101.6	9.5	Lv,	3110.6	9.5	Fn,	3111.6	9.0	V,	3111.7	9.4	Lv,
	3118.7	9.4	B,	3127.6	9.6	B,	3129.6	10.0	Pt,	3130.5	10.2	Pi,
	3131.7	10.3	Y.									
065208 X MONOCEROTIS—												
	3088.3	9.5	L,	3106.4	7.9	L,	3130.6	8.0	Hu.			
065355 R LYNCIS—												
	3111.4	11.6	Gi,	3130.5	11.0	Pi.	3131.7	10.6	Y.			
070109 V CANIS MINORIS—												
	3102.6	13.6	B,	3113.6	13.8	B.						
070122a R GEMINORUM—												
	3108 2	9.5	Ch,	3108.7	9.6	Pt,	3111.7	9.7	Lv,	3118.7	9.4	B,
	3130.6	9.5	Hu.									
070122b Z GEMINORUM—												
	3108.2<11.5		Ch,	3108.7	12.8	Pt,	3111.7	12.5	Lv,	3118.7	12.4	B.

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Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
070122c TW GEMINORUM—												
	3118.7	8.4	B.									
070310 R CANIS MINORIS—												
	3090.3	8.0	L,	3106.3	8.4	An.	3106.4	8.4	L,	3118.6	8.5	B,
	3127.7	8.5	B.									
071044 L[2] PUPPIS—												
	3111.1	4.4	Ch.									
071201 RR MONOCEROTIS—												
	3101.7	<13.4	Lv,	3113.6	<13.1	Lv.						
072708 S CANIS MINORUS—												
	3087.4	<10.0	Rk,	3090.3	12.2	L,	3104.1	11.0	Ch,	3105.7	11.4	Br,
	3106.4	11.2	L,	3108.7	10.9	Pt,	3111.4	11.0	Rk,	3117.6	11.0	Pc,
	3125.6	10.5	Pc.									
072811 T CANIS MINORIS—												
	3089 9	9.7	Kd,	3095.9	9.5	Kd,	3105.0	9.6	Kd,	3108.7	9.6	Pt,
	3118.7	10.0	B,	3127.6	10.5	B.						
072820b Z PUPPIS—												
	3105.7	11.5	Br,	3111.7	11.5	Br,	3117.5	<12.1	Fn.			
073508 U CANIS MINORIS—												
	3090.3	10.8	L,	3106.4	11.2	L,	3108 7	11.0	Pt,	3112.3	11.3	L,
	3118.7	11.5	B,	3127.7	11.5	B,	3131.7	11.6	Y.			
073723 S GEMINORUM—												
	3080.9	9.8	Kd,	3085.0	9.9	Kd,	3086.9	9.9	Kd,	3089.9	9.8	Kd,
	3095.9	9.7	Kd,	3103.0	10.0	Kd,	3105.0	10.0	Kd,	3108.7	10.2	Pt,
	3111.6	9.9	V,	3118.7	10.7	B.						
074323 T GEMINORUM—												
	3080.9	9.2	Kd,	3085.0	9.2	Kd,	3086.9	9.2	Kd,	3089.9	9.1	Kd,
	3095.9	9.0	Kd,	3103.0	8.9	Kd,	3105.0	8.9	Kd,	3111.6	9.0	V,
	3118.7	8.7	B,	3131.6	9.4	Hu.						
074922 U GEMINORUM—												
	3044.4	<13.0	Jp,	3047.4	<13.0	Jp,	3056.0	<13.3	Ym,	3057.0	<13.7	Ym,
	3057.9	<13.7	Ym,	3059.0	<13.3	Ym,	3061.1	<14.0	Ym,	3061.9	<13.7	Ym,
	3075.9	12.7	Ym,	3079.0	14.1	Ym,	3082.0	<13.7	Ym,	3087.4	<12.4	Rk,
	3088.4	<13.0	Dp,	3088.4	<13.0	Jp,	3090.4	<12.3	Rk,	3090.5	13.9	Gi,
	3093.4	<11.4	Rk,	3095.4	< 9.3	Rk,	3097.4	< 9.8	Rk,	3100.3	14.0	Gi,
	3100.4	<13.7	L,	3102.4	<12.4	Rk,	3102.4	13.9	Gi,	3102.6	13.9	B,
	3104.1	<12.4	Ch,	3105.6	<11.7	Br,	3105.7	13.9	Wf,	3106.3	13.9	L,
	3106.3	14.0	Gi,	3106.5	<13.3	Pt,	3106.7	13.9	Wf,	3107.4	<12.4	Rk,
	3107.7	14.0	B,	3108.6	<13.3	Pt,	3108.7	14.0	Wf,	3109.3	14.0	Gi,
	3109.3	13.9	L,	3109.7	13.8	Wf,	3110.3	14.0	Gi,	3110.6	<13.3	Pt,
	3110.7	14.1	Wf,	3111.0	<14.1	Ym,	3111.3	14.1	L,	3111.4	13.9	Gi,
	3111.4	<12.4	Rk,	3111.6	13.3	Fn,	3111.6	14.0	B,	3111.7	14.0	Wf,
	3111.7	<11.7	Br,	3111.8	<13.3	Pt,	3112.3	14.2	L,	3112.4	14.0	Gi,
	3112.7	14.0	Wf,	3113.3	<12.4	Rk,	3113.6	14.0	B,	3113.7	14.0	Wf,
	3114.3	<13.3	L,	3114.5	14.1	L,	3114.6	14.0	Pc,	3114.7	14.0	Wf,
	3115.7	14.2	Wf,	3116.5	<13.3	Pt,	3117.6	14.0	Pc,	3117.6	<12.4	Pt,
	3118.7	13.9	B,	3118.8	<12.3	Pt,	3118.9	14.0	Wf,	3119.7	14.0	Wf,
	3119.8	<13.3	Pt,	3129.6	<13.3	Pt,	3130.5	<12.3	Pi,	3130.6	<12.4	Pt,
	3131.7	<13.0	Y.									
075612 U PUPPIS—												
	3131.7	<12.5	Y.									
081112 R CANCRI—												
	3100.3	8.4	L,	3104.1	7.9	Ch.	3108.7	7.5	Pt,	3111.3	8.0	L,
	3111.4	7.9	Rk.									
081617 V CANCRI—												
	3102.4	8.0	Gi,	3105.7	7.7	Br,	3107.6	8.4	B,	3108.6	7.5	Pt.
082405 RT HYDRAE—												
	3088.3	7.4	L,	3106.4	7.8	L,	3107.6	8.0	B.	3129.6	7.9	Pt.
083019 U CANCRI—												
	3105.8	12.7	Wf,	3114.7	13.9	Wf,	3119.8	14.0	Wf.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
083350 X URSAE MAJORIS—												
	3102.6	13.2	B.	3113.6	13.8	B.						
084803 S HYDRAE—												
	3059.0	12.8	Ym,	3104.1	11.0	Ch,	3105.7	10.6	Br,	3106.6	10.5	B,
	3108.6	10.4	Pt.									
085008 T HYDRAE—												
	3104.1	9.3	Ch,	3105.8	9.3	Br,	3106.4	9.8	L,	3106.6	9.3	B,
	3108.6	9.3	Pt.									
085120 T CANCRI—												
	3090.3	8.4	L,	3108.6	8.6	Pt,	3109.4	11.4	L,	3112.3	11.6	L.
090024 S PYXIDIS—												
	3108.6	10.7	Pt.									
090151 V URSAE MAJORIS—												
	3113.7	10.2	Sg,	3116.6	10.2	B,	3127.6	10.4	B.			
090425 W CANCRI—												
	3090.3	9.8	An,	3105.8	11.2	Wf,	3111.6	<10.8	V,	3114.7	11.5	Wf,
	3116.6	11.8	B,	3119.8	12.1	Wf.						
093014 X HYDRAE—												
	3113.6	11.0	B.									
093178 Y DRACONIS—												
	3113.6	14.0	B.									
093934 R LEONIS MINORIS—												
	3090.3	8.6	L,	3104.1	7.6	Ch,	3106.3	7.6	An,	3106.4	7.3	L,
	3108.6	7.0	Pt,	3110.6	7.4	Pc,	3116.6	7.0	B,	3117.6	7.4	Pc,
	3125.6	7.5	Pc,	3131.6	6.5	Hu.						
094211 R LEONIS—												
	3059.0	7.2	Ym,	3061.0	7.3	Ym,	3076.0	7.9	Ym,	3104.1	8.2	Ch,
	3108.6	7.8	Pt,	3109.7	8.2	Br,	3110.6	8.0	Pc,	3111.0	8.3	Ym,
	3111.4	7.6	Rk,	3111.6	8.0	Ms,	3114.6	8.0	Ms,	3116.6	8.1	B,
	3117.6	8.0	Pc,	3120.6	8.2	Ms,	3125.6	8.0	Pc,	3131.6	8.7	Pw.
094512 X LEONIS—												
	3059.0	<13.3	Ym,	3061.0	<13.3	Ym,	3076.0	11.9	Ym,	3079.0	12.5	Ym,
	3082.0	<13.3	Ym,	3090.3	12.3	An,	3090.4	12.3	L,	3100.4	<12.8	L,
	3106.3	<13.3	L,	3109.3	12.0	An,	3109.4	12.1	L,	3110.6	12.3	L,
	3111.0	12.3	Ym,	3111.3	12.6	L,	3111.6	12.7	L,	3112.3	12.9	An,
	3112.3	12.8	L,	3112.7	13.6	L,	3114.5	<13.6	L.			
095421 V LEONIS—												
	3105.8	12.1	Wf,	3108.6	12.7	Pt,	3114.7	12.7	Wf,	3116.6	12.5	B,
	3119.8	12.6	Wf.									
103212 U HYDRAE—												
	3090.7	4.7	L,	3109.6	5.0	L.						
103769 R URSAE MAJORIS—												
	3104.1	<11.5	Ch,	3108.6	12.9	Pt,	3110.6	12.5	Pc,	3113.6	12.3	B,
	3113.7	<10.5	Sg,	3117.6	13.0	Pc,	3131.6	11.2	Pw.			
104610 V HYDRAE—												
	3090.7	7.5	L,	3104.2	8.3	Ch,	3108.6	8.1	Pt,	3111.4	7.8	L,
104814 W LEONIS—												
	3108.6	9.7	Pt,	3113.6	9.4	B,	3131.7	9.8	Y.			
110506 S LEONIS—												
	3102.6	10.1	B,	3108.6	10.8	Pt,	3120.6	12.2	B.			
115919 R COMAE BERENICES—												
	3102.7	<13.4	B,	3105.8	14.5	Wf,	3108.7	14.0	Wf,	3111.8	<12.2	Br,
	3114.8	14.0	Wf,	3119.8	<14.0	Wf.						
120012 SU VIRGINIS—												
	3131.6	8.5	Pw.									
120905 T VIRGINIS—												
	3111.9	<11.4	Br,	3131.6	<11.0	Pw.						
121418 R CORVI—												
	3091.3	10.6	Ym,	3109.7	10.5	L,	3111.8	10.2	Pt.			

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.Obs.	J.D.	Est.Obs.	J.D.	Est.Obs.	J.D.	Est.Obs.
122001 SS VIRGINIS—								
	3106.7	7.9 L.						
122532 T CANUM VENATICORUM—								
	3108.6	10.9 Pt,	3111.8	11.0 Br,	3131.6	8.2 Pw.		
122803 Y VIRGINIS—								
	3106.7	10.0 L,	3111.9	9.9 Br.				
123160 T URSAE MAJORIS—								
	3079.1	9.0 Ym,	3104.2	10.3 Ch,	3106.7	10.0 Sg,	3108.6	10.2 Pt.
	3110.6	10.9 Pc,	3111.7	10.6 Br,	3113.7	11.0 Sg,	3114.6	11.0 Pc,
	3116.6	11.2 B,	3117.7	11.0 Sg,	3119.5	<9.8 Mc,	3119.8	11.0 Sg,
	3125.7	<9.8 Sg.	3131.6	12.0 Pc.				
123307 R VIRGINIS—								
	3106.7	9.4 L,	3108.6	9.8 Pt,	3131.7	11.0 Pw.		
123459 RS URSAE MAJORIS—								
	3079.1	<13.2 Ym,	3104.2	<11.0 Ch,	3105.8	14.1 Wf,	3111.7	<12.2 Br,
	3114.6	13.8 Pc,	3114.8	13.9 Wf,	3116.7	<13.5 B,	3119.5	< 9.9 Mc.
123961 S URSAE MAJORIS—								
	3090.3	8.5 An,	3090.4	8.6 L,	3104.1	8.5 Ch,	3106.7	8.2 Sg,
	3108.6	8.3 Pt,	3109.3	8.1 L,	3109.3	8.8 An,	3110.6	8.5 Pc,
	3111.7	8.3 Br,	3113.7	8.6 Sg,	3114.6	8.2 Pc,	3117.7	8.4 Sg,
	3119.5	7.7 Mc,	3119.8	8.5 Sg,	3120.8	8.0 Sg,	3125.7	8.0 Sg,
	3127.6	7.7 B,	3131.6	7.6 Pc.				
124606 U VIRGINIS—								
	3108.6	10.8 Pt.						
130212 RV VIRGINIS—								
	3091.3	13.6 Ym,	3108.9	14.2 Wf,	3119.9	<13.8 Wf.		
132422 R HYDRAE—								
	3052.5	4.2 Ch,	3062.4	4.3 Ch,	3078.4	4.9 Ch,	3081.3	5.2 Kd,
	3085.3	5.2 Kd,	3087.4	5.2 Ch,	3089.3	5.4 Kd,	3090.7	5.5 Gi,
	3091.3	5.5 Ym,	3093.4	5.5 Ch,	3096.3	5.6 Kd.	3103.3	5.8 Kd,
	3106.7	6.0 L,	3108.2	6.0 Pt,	3109.6	5.8 Gi,	3111.8	6.2 Pt.
132706 S VIRGINIS—								
	3108.2	7.6 Ch,	3111.8	7.5 Pt.				
133273 T URSAE MINORIS—								
	3105.8	13.4 Wf,	3114.8	13.3 Wf.				
134440 R CANUM VENATICORUM—								
	3120.7	8.5 B.						
135908 RR VIRGINIS—								
	3111.8	11.6 Pt.						
140113 Z BOOTIS—								
	3108.8	9.4 Wf,	3114.8	9.3 Wf,	3119.9	8.9 Wf.		
141567 U URSAE MINORIS—								
	3109.2	9.4 Ch,	3111.8	9.2 Pt,	3114.6	9.1 Pc.		
141954 S BOOTIS—								
	3090.5	11.9 Gi,	3090.7	11.9 L,	3109.2	<11.6 Ch,	3110.7	12.5 L,
	3111.5	12.4 Gi,	3111.8	12.7 Pt.				
142539 V BOOTIS—								
	3090.7	8.7 L,	3109.5	8.5 Mc,	3109.7	7.7 L,	3111.8	7.8 Pt,
142584 R CAMELOPARDALIS—								
	3105.8	11.7 Wf,	3106.4	11.9 Gi,	3111.7	11.5 Br,	3114.8	11.5 Wf.
143227 R BOOTIS—								
	3109.3	9.9 Ch,	3111.8	9.8 Pt,	3111.8	9.4 Br,	3114.8	10.4 Sg,
	3117.8	11.0 Sg.	3119.8	<10.5 Sg,	3121.8	11.2 Sg.		
143417 V LIBRAE—								
	3112.0	9.8 Br.						
144918 U BOOTIS—								
	3090.5	10.8 Gi,	3111.7	9.8 Gi.				
150018 RT LIBRAE—								
	3111.8	8.5 Pt,	3112.0	8.6 Br.				

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
150605 Y LIBRAE—												
	3106.7	8.5	L,	3111.8	8.2	Pt.						
151520 S LIBRAE—												
	3109.7	10.6	L,	3111.8	10.4	Pt,	3112.4	10.5	Ch.			
151714 S SERPENTIS—												
	3090.7	13.5	L,	3108.8	13.5	Wf,	3109.7	13.7	L,	3114.8	13.2	Wf,
	3119.8	13.5	Wf.									
151731 S CORONAE BOREALIS—												
	3105.8	9.0	Wf,	3108.8	8.7	Wf,	3111.8	9.0	Br,	3111.8	8.9	Pt,
	3112.3	9.1	Ch,	3114.8	8.5	Wf,	3119.9	8.8	Wf.			
151822 RS LIBRAE—												
	3109.7	11.4	L.									
152714 RU LIBRAE—												
	3090.7<13.1		L,	3109.7<13.1		L.						
153215 W LIBRAE—												
	3090.7	13.5	L,	3109.7<13.1		L.						
153378 S URSAE MINORIS—												
	3079.1	11.0	Ym,	3105.8	11.4	Wf,	3111.8	10.6	Br,	3111.8	10.7	Pt,
	3114.8	10.4	Wf.									
154428 R CORONAE BOREALIS—												
	3052.5	6.0	Ch,	3079.3	6.0	Ym,	3090.7	6.5	Gi,	3090.7	6.3	L,
	3091.3	6.3	Ym,	3093.4	6.2	Ch,	3104.3	6.5	Ym,	3105.8	6.8	Wf,
	3105.8	6.3	Pt,	3106.8	6.6	Wf,	3108.7	6.2	Pt,	3108.9	6.6	Wf,
	3109.6	6.5	Gi,	3109.6	6.3	L,	3110.6	6.3	L,	3111.6	6.2	L,
	3111.7	6.9	Ms,	3111.8	6.0	Pt,	3112.0	6.2	Wf,	3112.3	6.3	Ch.
	3112.7	6.3	L,	3112.7	6.7	Ms,	3113.0	6.2	Wf,	3113.8	6.4	Wf,
	3114.5	6.1	L,	3114.8	6.4	Wf,	3116.8	6.2	Pt,	3117.8	6.1	Pt,
	3118.8	6.1	Pt,	3119.8	6.2	Pt,	3119.9	6.2	Wf,	3120.7	6.7	Ms,
	3121.8	6.8	Sg,	3122.8	6.2	Pt,	3124.8	6.0	Wf,	3125.7	6.2	Pt,
	3129.6	6.1	Pt,	3132.7	6.7	Ms.						
154536 X CORONAE BOREALIS—												
	3108.8	13.3	Wf,	3114.8	8.0	Wf,	3119.9	8.2	Wf.			
154615 R SERPENTIS—												
	3111.8	6.6	Pt,	3112.4	7.0	Ch.						
154639 V CORONAE BOREALIS—												
	3111.8	8.5	Pt,	3111.9	8.4	Br.						
154715 R LIBRAE—												
	3112.0<11.0		Br.									
155018 RR LIBRAE—												
	3112.4<11.9		Ch,	3110.7	14.1	L.						
155823 RZ SCORPII—												
	3118.8	12.2	Pt.									
160021 Z SCORPII—												
	3110.7	10.9	L.									
160118 R HERCULIS—												
	3112.4<11.5		Ch.									
160210 U SERPENTIS—												
	3111.8	10.3	Pt,	3111.9	10.5	Br.						
160625 RU HERCULIS—												
	3108.8	10.8	Wf,	3114.8	10.8	Wf,	3118.8	10.9	Pt.	3119.8	10.8	Wf.
161122a R SCORPII—												
	3118.8	10.7	Pt.									
161138 W CORONAE BOREALIS—												
	3108.8	13.1	Wf,	3111.9<11.2		Br,	3114.8	13.0	Wf,	3119.9	13.0	Wf.
161607 W OPHIUCHI—												
	3090.7	12.7	L,	3110.7	11.3	L,	3111.8	11.3	Pt.			
162112 V OPHIUCHI—												
	3111.8	9.5	Pt.									
162119 U HERCULIS—												
	3103.7	7.8	Gi,	3111.8	7.8	Pt,	3111.9	8.5	Br,	3112.3	8.0	Ch.

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
162807 SS HERCULIS—												
	3106.7	9.8	L.	3111.8	9.4	Pt.	3111.9	9.7	Br.			
162815 T OPHIUCHI—												
	3110.7	11.5	L.	3122.9	11.1	Pt.						
162816 S OPHIUCHI—												
	3090.7	10.2	L.	3110.7	10.1	L.						
163137 W HERCULIS—												
	3111.9	10.8	Br.	3112.3	10.6	Ch.	3116.8	10.6	Pt.			
163266 R DRACONIS—												
	3111.8	10.1	Pt.	3111.8	10.2	Br.	3112.3	10.4	Ch.	3114.6	10.0	Pc.
164319 RR OPHIUCHI—												
	3110.7	<12.0	L.	3111.7	12.6	L.						
164715 S HERCULIS—												
	3102.6	7.9	Gi.	3111.8	8.4	Pt.	3111.9	8.4	Br.			
165631 RV HERCULIS—												
	3079.3	<13.4	Ym.									
170215 R OPHIUCHI—												
	3116.8	8.0	Pt.									
170627 RT HERCULIS—												
	3108.9	11.4	Wf.	3112.0	11.2	Br.	3114.9	11.7	Wf.	3116.8	11.7	Pt.
	3119.9	11.8	Wf.									
171401 Z OPHIUCHI—												
	3103.7	8.0	Gi.	3112.0	8.4	Br.	3116.8	8.4	Pt.			
171723 RS HERCULIS—												
	3108.9	11.2	Wf.	3112.0	10.7	Br.	3114.9	10.5	Wf.	3116.8	10.5	Pt.
	3119.9	10.1	Wf.									
172809 RU OPHIUCHI—												
	3112.0	<12.2	Br.	3116.8	12.6	Pt.						
173212 RT SERPENTIS—												
	3111.7	9.3	L.									
174406 RS OPHIUCHI—												
	3116.8	11.6	Pt.									
175111 RT OPHIUCHI—												
	3116.8	12.0	Pt.									
175458a T DRACONIS—												
	3111.8	<11.7	Br.									
175458b UY DRACONIS—												
	3111.8	11.1	Br.									
175519 RY HERCULIS—												
	3112.0	9.4	Br.	3113.5	9.5	Ch.						
180531 T HERCULIS—												
	3106.7	12.7	L.	3112.0	12.5	Br.	3113.5	12.0	Ch.	3116.9	12.7	Pt.
180666 X DRACONIS—												
	3111.8	11.8	Pt.									
180911 NOVA OPHIUCHI #4—												
	3111.7	11.8	L.									
181031 TV HERCULIS—												
	3110.7	12.4	L.									
181103 RY OPHIUCHI—												
	3090.7	7.9	Gi.	3110.7	8.9	Gi.	3113.0	9.9	Wf.			
181136 W LYRAE—												
	3109.7	9.8	L.	3116.9	10.0	Pt.						
182224 SV HERCULIS—												
	3090.7	14.0	L.	3110.7	14.0	L.	3111.6	14.2	L.			
182306 T SERPENTIS—												
	3116.9	10.0	Pt.									
183225 RZ HERCULIS—												
	3116.9	9.4	Pt.									
183308 X OPHIUCHI—												
	3109.7	7.0	L.	3116.9	6.9	Pt.						

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
184205 R SCUTI—												
	3109.7	5.3	L.	3114.7	5.0	Gi.	3116.9	5.4	Pt,	3117.9	5.3	Pt,
	3118.9	5.4	Pt,	3122.9	5.6	Pt.						
184300 NOVA AQUILAE #3—												
	3111.7	10.2	L,	3116.9	9.8	Pt,	3122.9	9.9	Pt.			
185634 Z LYRAE—												
	3110.7	14.3	L.	3111.7	14.8	L.						
190108 R AQUILAE—												
	3116.9	11.8	Pt.									
190925 S LYRAE—												
	3111.7	<15.0	L.									
190926 X LYRAE—												
	3117.9	8.8	Pt.									
190933a RS LYRAE—												
	3117.9	12.8	Pt.									
190967 U DRACONIS—												
	3112.0	10.1	Br,	3117.9	10.8	Pt.						
191350 TZ CYGNI—												
	3043.4	11.0	Jp,	3043.4	10.8	Dp,	3057.6	11.0	To,	3064.6	11.0	To,
	3077.6	11.0	To,	3117.9	10.8	Pt.						
193449 R CYGNI—												
	3043.4	<13.1	Jp,	3043.4	<13.1	Dp,	3057.6	<12.1	To,	3077.6	<11.5	To,
	3087.6	<11.0	To,	3112.1	11.7	Br,	3113.5	10.9	Ch,	3118.9	11.3	Pt.
193509 RV AQUILAE—												
	3043.2	13.0	Jp,	3043.2	13.0	Dp.						
194048 RT CYGNI—												
	3103.7	7.6	Gi,	3118.9	7.9	Pt.						
194348 TU CYGNI—												
	3043.4	9.5	Jp,	3043.4	9.5	Dp,	3044.4	9.5	Jp,	3044.4	9.5	Dp,
	3112.1	<12.1	Br.									
194604 X AQUILAE—												
	3113.0	9.8	Wf,	3118.9	9.8	Pt.						
194632 χ CYGNI—												
	3043.2	9.7	Jp,	3043.2	9.7	Dp,	3044.2	9.9	Jp,	3044.2	9.8	Dp,
	3057.6	10.8	To,	3057.9	11.1	Ym,	3064.6	10.9	To,	3079.3	11.3	Ym.
195202 RR AQUILAE—												
	3043.2	<12.7	Jp.									
195653 NOVA CYGNI #3—												
	3044.2	10.6	Jp,	3044.2	10.6	Dp,	3057.0	9.9	Ym,	3062.0	10.2	Ym,
	3075.0	10.0	Ym,	3090.9	9.8	Ym,	3111.8	10.0	Pt,	3112.7	9.7	L,
	3116.9	9.6	Pt,	3117.9	10.0	Pt,	3122.8	9.6	Pt.			
195849 Z CYGNI—												
	3043.2	12.3	Jp,	3043.2	12.3	Dp,	3057.6	<11.7	To,	3087.6	<11.6	To,
	3105.6	<13.5	Wf,	3113.0	14.0	Wf.						
200212 SY AQUILAE—												
	3090.7	9.1	L,	3110.7	8.8	L,	3118.9	8.9	Pt.			
200357 S CYGNI—												
	3112.1	11.0	Br.	3118.9	10.5	Pt.						
200715a S AQUILAE—												
	3114.7	9.6	Gi,	3118.9	10.8	Pt.						
200938 RS CYGNI—												
	3111.7	7.7	L,	3118.9	7.3	Pt.						
201647 U CYGNI—												
	3103.7	7.9	Gi,	3118.9	7.0	Pt.						
202817 Z DELPHINI—												
	3118.9	10.1	Pt.									
202946 SZ CYGNI—												
	3122.9	9.3	Pt.									
202954 ST CYGNI—												
	3118.9	10.9	Pt.									

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
203226 V VULPECULAE—												
	3118.9	8.5	Pt.									
204016 T DELPHINI—												
	3113.0	11.6	Wf,	3118.9	12.0	Pt.						
205923 R VULPECULAE—												
	3111.7	13.0	Gi.									
210868 T CEPHEI—												
	3088.3	8.0	L,	3106.4	7.4	L,	3106.5	7.5	Pt.			
213244 W CYGNI—												
	3055.9	6.5	Ym,	3057.0	6.4	Ym,	3057.9	6.4	Ym,	3058.9	6.5	Ym,
	3059.9	6.4	Ym,	3061.0	6.4	Ym,	3062.0	6.4	Ym,	3062.9	6.6	Ym,
	3066.9	6.5	Ym,	3075.9	6.9	Ym,	3090.9	6.7	Ym,	3109.3	5.9	L.
213678 S CEPHEI—												
	3106.5	9.5	Pt,	3111.4	8.7	Gi,	3112.0	9.9	Br.			
213843 SS CYGNI—												
	3043.3	11.8	Jp,	3043.3	11.7	Dp,	3044.3	11.8	Jp,	3044.3	11.8	Dp.
	3055.9	11.6	Ym,	3057.0	11.6	Ym,	3057.6	11.8	To,	3057.9	11.7	Ym,
	3058.9	12.0	Ym,	3059.9	12.0	Ym,	3061.0	11.7	Ym,	3061.9	11.8	Ym.
	3062.9	12.0	Ym,	3064.6	<11.0	To,	3064.9	11.8	Ym,	3065.9	11.8	Ym,
	3075.9	11.8	Ym,	3077.6	12.0	To,	3080.7	12.0	To,	3080.7	12.0	Jb,
	3081.9	11.5	Ym,	3084.9	11.3	Ym,	3086.9	8.4	Kd,	3087.3	8.4	Gi,
	3087.7	8.2	To,	3088.2	8.2	An,	3088.2	8.3	L,	3088.6	8.3	To,
	3088.6	8.0	Jb,	3089.6	8.0	Jb,	3089.9	8.4	Kd,	3090.2	8.2	L,
	3090.2	8.2	An,	3090.3	8.3	Gi,	3090.9	8.7	Ym,	3091.4	8.5	Ym,
	3091.6	8.5	Jb,	3095.3	8.4	L,	3095.3	8.3	An,	3095.3	8.9	Gi,
	3095.9	8.8	Kd,	3098.6	9.2	To,	3100.3	9.8	Gi,	3102.3	10.8	Gi,
	3105.6	11.8	Wf,	3106.3	11.2	Gi,	3106.3	11.8	L,	3106.5	11.3	Pt,
	3106.7	11.2	Wf,	3107.5	11.0	Ms,	3108.6	11.8	Wf,	3109.2	11.6	An,
	3109.3	11.2	Gi,	3109.3	11.5	L,	3109.7	11.7	Wf,	3110.7	10.9	Wf,
	3110.7	10.6	L,	3110.7	11.2	Gi,	3111.5	<11.7	Fn,	3111.7	11.2	Gi,
	3111.7	11.1	Wf,	3111.7	10.8	L,	3111.8	11.9	Pt,	3112.1	11.5	Br,
	3112.2	11.2	L,	3112.7	11.1	Wf,	3113.5	<11.5	Ch,	3113.7	11.2	Wf,
	3114.6	11.1	Wf,	3114.7	11.2	Gi,	3116.9	11.5	Pt,	3117.9	11.6	Pt,
	3118.9	11.8	Pt,	3119.6	11.3	Wf,	3122.9	11.9	Pt,	3124.7	11.6	Wf.
213937 RV CYGNI—												
	3118.9	7.0	Pt.									
222129 RV PEGASI—												
	3113.6	<12.3	B.									
222439 S LACERTAE—												
	3102.3	11.9	Gi,	3109.3	11.3	L.						
223841 R LACERTAE—												
	3102.3	14.0	Gi,	3109.3	13.0	L.						
230110 R PEGASI—												
	3089.6	9.5	Jb.									
230759 V CASSIOPEIAE—												
	3090.4	8.3	Gi,	3111.4	8.3	Gi,	3122.5	8.6	B,	3129.5	9.0	Pt.
231425 W PEGASI—												
	3109.3	8.1	L.									
233335 ST ANDROMEDAE—												
	3082.0	9.0	Ym,	3090.9	8.8	Ym,	3107.1	8.6	Ch,	3105.7	8.8	Wf,
	3114.6	8.2	Wf,	3124.7	8.4	Wf,	3129.5	8.7	Pt.			
233815 R AQUARII—												
	3080.9	6.8	Kd,	3089.9	7.3	Kd.						
233956 Z CASSIOPEIAE—												
	3105.7	12.5	Wf,	3114.6	13.1	Wf,	3120.6	<12.6	B,	3124.7	13.3	Wf.
235053 RR CASSIOPEIAE—												
	3090.4	10.8	Gi,	3111.3	10.5	Gi,	3122.5	10.9	B.			
235350 R CASSIOPEIAE—												
	3090.4	9.2	Gi,	3110.3	9.6	Gi.						

VARIABLE STAR OBSERVATIONS, February 20 to March 20, 1922—Continued.

Star	J.D.	Est.Obs.	J.D.	Est.Obs.	J.D.	Est.Obs.	J.D.	Est.Obs.
235715 W CETI—								
	3090.3	8.7 Gi.						
235855 Y CASSIOPEIAE—								
	3090.5	9.8 Gi,	3111.3	9.9 Gi,	3118.6	10.5 B.		

Total Observations: 1220. Total Stars: 240. Observers: 27.

COMMUNICATIONS.

Mars Beginning to Show Details.—Amateurs may be interested to know that already Mars is beginning to show some definite markings that may be seen in a telescope of moderate aperture. On Feb. 1 I was able to see an indistinct dark center. By Feb. 20 it was definite enough in good seeing so that a layman unaccustomed to using a telescope was able to see it definitely. At the present writing (March 23) it is quite definite and near enough so it stands quite a power and so makes a fair sized disk possible. But it will not stand poor seeing. The seeing was poor the morning of the 22nd and the dark outline was indistinct and unsatisfactory. My views were made through my 5½-inch Brashear refractor.

It needs strong emphasis that there is great value in mounting a telescope on a very firm pier or similar mounting. An instrument will deliver much better results this way. I have made a cement pier for mine. One costs little and pays big dividends.

I have not yet been able to make out any green hues on the surface, but it seemed to me that I could distinguish the ochre color of the desert area. I have been expecting to see the polar caps, but must admit my being unable to do so.

On April 1 Mars is still 81,772,000 miles away. When this is considered it is especially encouraging that the planet shows up as distinct details as it does in a moderate sized instrument.

On May 1 Mars is 59,235,000 miles away; 42,357,275 miles on June 18, at its nearest approach.

Oakland, Iowa. RUEL W. ROBERTS.

Shadow of Titan.—In POPULAR ASTRONOMY for December 1921, Prof. Pickering records an interesting observation of the transit of TITAN across the disc of Saturn on 1921 April 8, which agrees well with the ephemeris published in the Journal of the B. A. A. (XXXI, p. 119). He was, however, unable to observe the shadow of the satellite, and concludes that, in this respect, the ephemeris was incorrect.

The heliocentric position of TITAN, on which the prediction of the shadow transit was based, received striking confirmation by the eclipse of RHEA by the shadow of TITAN predicted from the same computation and observed on the same date as Prof. Pickering's observation (M. N. LXXXI, p. 486). On examination of the position of the shadow, we find, however, that it would be hidden from a terrestrial observer by the rings, its centre being just on the projection of the inner edge of ring B at mid-transit. This satisfactorily accounts for the non-appearance of the shadow.

L. J. COMRIE AND A. E. LEVIN.

Gravitation.—Notwithstanding Mr. Julian L. Coolidge's somewhat amusing account in your February issue of the low values which some astronomers place upon the theories of their rivals, I am doubtful whether a layman will be permitted to butt into your quite exclusive circle. Yet I will try.

It seems to me Professor Pickering was not consistent (in your March issue) in first holding that there is no place for "force" in explaining gravitation and then advancing the theory that the ether "squeezes" bodies in all directions along radial lines towards a body from which lines or tubes of force emanate. Whatever "squeezes" bodies with the effect of translationally deflecting them comes within the category "force," as the term has always been understood, does it not?

But waiving this, let us adopt Professor Pickering's theory that the ether squeezes bodies. Only let us suppose that instead of squeezing them in some mysterious way, it squeezes them precisely as all other gases squeeze bodies. Then, if for any reason the ether is less dense between two bodies in proximity than elsewhere the squeezing would tend to push them towards each other, would it not?

Let us now recall Mendelieff's tentative theory that the ether is the most attenuated gas, whose molecules are far swifter than those of hydrogen. Also Le Sage's conception of "ultramundane particles" of enormous velocity; and Preston's conception of the enormous thrust (mean free path) of these particles. Let us suppose that the Le Sage-Preston particles and Mendelieff's ether molecules are identical (etherons would be a good name for them) and that *some* of them have a thrust longer than the radius of the solar system. Now let me quote a definition that I wrote about 1910:

Gravitation is that component of a body's translatory motion or tendency, which is due to a differential in the bombardment it receives from the fluid medium in which it is immersed, when the said differential is caused by the shielding of the body from some of the bombardment which it would receive equally from all directions if it were isolated; the said shielding arising when another body in proximity deflects particles of the medium having longer free paths than the distance between the bodies, and which being headed for the first body, either fail to strike it, or strike it with diminished effect, because of being deflected by the first body.

If by unexpected chance it would be of interest to you, I should be happy to tell you how I think the ether—which here on earth, is dense, with a mean free path of the order of magnitude of molecules—in reaching interstellar space acquires the enormous thrust and velocity and corresponding kinetic energy which is adequate to deflect planets from tangential into orbital courses: in other words how the requisite energy is imparted to the ether, with which to "squeeze bodies along radial lines" towards other bodies—as Professor Pickering is convinced it does.

Hotel Bradley Rush Street and East Grand Ave., Chicago, March 24, 1922.

L. G. Bostedo.

GENERAL NOTES.

Professor H. C. Plummer has resigned as Astronomer Royal of Ireland to accept the professorship of mathematics at the Ordnance College, Woolwich.

Dr. M. Maggini has been elected to a position in the observatory in Catania.

The American Section of the International Astronomical Union met in Washington at the offices of the National Research Council on April 3 and 4, 1922, about twenty members being present. The Section spent the two days in discussing the reports of committees and in considering other matters for the instruction of the American delegates to the International conference in Rome, which opens on May 2. Some of the delegates were at the Washington meeting, but others had already started for abroad. The personnel of the delegation, as it was finally constituted, is as follows: Frank Schlesinger, *Chairman;* R. G. Aitken, L. A. Bauer, William Bowie, H. D. Curtis, Edward Kasner, O. J. Lee, F. B. Littell, J. A. Mitchell, H. N. Russell, F. H. Seares, Harlow Shapley, C. E. St. John. A full record of the various committee reports, and an account of the Rome meeting will be published later.

It is expected that some of the American astronomers will be able to return by way of England and be present at the centenary celebration of the Royal Astronomical Society, which will take place on May 29 and 30.

JOEL STEBBINS, *Secretary.*

The Cleveland Astronomical Society.— The Cleveland Astronomy Club held a second meeting on April 10, at which time it was decided to name the organization the Cleveland Astronomical Society. About three dozen people were present and officers were elected for the year ending April 1, 1923, as follows:

President: Jason J. Nassau, Professor of Mathematics and Astronomy, Case School of Applied Sciences.
Vice President: Mrs. Curt B. Muller.
Sec'y-Treasurer: Albert F. Schroeder.

Executive Committee: The above officers and Miss Louise Klein Miller, Mrs. W. A. Neff, Mr. William A. Searles, and Mr. Curt B. Muller.

The Society will meet twelve times a year and will occasionally hold its meetings at the Observatory of the Case School of Applied Sciences. It will be invited to visit the observatories and use the telescopes which belong to various members of the Society.

At the meeting of April 10 a lecture was given by Prof. O. L. Dustheimer, of Baldwin-Wallace College of Berea, Ohio. The lecture was illustrated by means of a tellurian and lantern slides, and was very instructive and entertaining in character.

The next meeting of the Society will be held in May, quite probably at the Warner and Swasey Observatory of Case College, on Taylor Road, East Cleveland.

The list of actual and prospective members has already reached the number of 70. Any person, interested in astronomy or desiring to acquire more knowledge of the subject, is invited to join the Society. Further information can be obtained from the Secretary, Mr. Albert F. Schroeder, 1075 Forest Cliff Drive, Lakewood, Cleveland, Ohio.

The John H. Darling Observatory at Duluth, Minn., is open to the public and has completed five years of its existence. It was built by Mr. Darling out of his own funds, but upon land donated by the city of Duluth. It is usually open to the public on about seven nights of each month, during the time in which the moon is best seen. Planets and stars are also sometimes viewed with the excellent 9-inch telescope. From fifteen to twenty persons, as a rule, are accommodated at a time. Explanatory descriptions are given at the telescope and an illustrated talk is also given in the waiting room. An evening session occupies from two to two and a half hours. Sometimes daylight parties come and view the sun and Venus or Mercury, which two planets can be best seen in the daytime.

Mr. Darling, in an article in the *Duluth Herald* of April 21, 1922, says.

"The public has freely responded to my invitations. I find 4,093 names on the visitors' register at this writing. These are not all new or different names, as some have come a second time or oftener. Many have been turned away as the applications are usually beyond the capacity of the building. These people who wish to contemplate celestial things come as individuals and in groups; many students and teachers from the Duluth state teachers' college, from the high schools, the grade schools, the summer school or rural teachers of St. Louis county, literary societies, various clubs, Boy Scouts, Girl Scouts, etc. Many Superior people have been among my visitors, including classes from the normal and other schools.

"The visitors have generally seemed very appreciative and pleased with what they saw and heard. Many have evinced a keen interest in astronomy. Often questions are asked and sometimes a profitable discussion follows. Very frequently I meet a person on the street and elsewhere whom I do not recollect, but who greets me and speaks of his visit to my observatory, and many mention my monthly communications printed in The Herald with favorable comment. This is all very gratifying to me. The feeling that I am giving something of value to our citizens and their appreciation of same go far towards rewarding me for my efforts."

A Peculiar Star. —In the *Comtes Rendus* for January 9, MM. C. Nordmann and Le Morvan of the Paris Observatory call attention to the star 13 Cephei (B. D. +55° 2644). The star, which is of the sixth magnitude, has a spectrum of A-type, according to observations at Harvard, while its color is given as WG+ (whitish yellow) in the Potsdam catalogue. As A-type stars are usually called either white or bluish white in color the Paris observers put the star on the observing list of their "heterochrome" photometer. This instrument showed that the light of the star is very strong in the red end of the spectrum so that its effective temperature, computed according to Planck's law, is only 5130° absolute, while the average A-type star gives an effective temperature of about 9000°. There must be something very peculiar about the reversing layer of this star to account for this anomaly.

Spectrum of Omicron Ceti.—In *Lick Observatory Bulletin* 335, Dr. C. D. Shane summarizes results obtained by him with five different spectrographs in 1919 as follows:

1. More than sixty absorption bands in the visual region were measured.

Most of these belong to the titanium oxide band spectrum, but a few may possibly be due to yttrium.

2. As o Ceti grew fainter the red end of the visual spectrum became relatively strengthened. At the same time the absorption bands became more prominent.

3. The first seventeen lines of the Balmer hydrogen series were observed as bright lines.

4. Coincidences of certain abnormally faint hydrogen emission lines with strong lines of iron and vanadium suggest that their intensities are reduced through absorption by overlying metallic vapors.

5. The hydrogen line Hα was displaced 1A toward the violet with reference to the other hydrogen lines. Hκ, on the contrary, was displaced 1A toward the red at maximum light, whereas two months later it was approximately in its normal position.

Star Densities.—A correspondent asks which is the densest known star. This is a difficult question to answer, since all calculations of the densities of stars are necessarily very uncertain, but the best studies indicate that the average density is much smaller than that of the sun.

Approximate densities for 39 binary stars are given by E. Öpik in the *Astrophysical Journal* Vol. 44, p. 292. The range for these stars is from 0.01 to 5.9 times the sun's density. The star to which density 5.9 is assigned is η Cassiopeiae, but the author states that the elements of the orbit of this star are too uncertain to determine its density.

The following table is interesting as showing a progression of density with the spectral type of the star. The unit of density is that of the sun.

Spectral Type	No. of Stars	Average Density
A0-A5	9	0.65
F0-F8	19	0.59
G	7	0.23
K, K5	5	0.07
		Average 0.39

The Trapezium in the Orion Nebula.—Mr. Fred. S. Carrington, of Washta, Iowa, calls attention to possible variation in brightness of the sixth magnitude star at the upper right corner of the "Trapezium" in the great Nebula of Orion. He says:

"On Sunday evening, April 9, at 8:30 P. M., I was in my observatory with a visitor. On turning the telescope on the Orion nebula I was surprised to notice the very bright appearance of the 6 mag. star in the upper right hand corner of the Trapezium. I had picked up the nebula several times during the winter but saw nothing unusual."

Mr. David E. Hadden, of Alta, Iowa, on being notified of this peculiarity by Mr. Carrington, observed the Trapezium on April 11 and was also "struck with the very bright appearance of the 6 mag. star, namely A."

There are many variable stars listed within the Orion nebula, but the upper star of the Trapezium, or θ^1 Orionis is not one of them. The observers perhaps have been misled by the different notation in different books. According to Burnham's Catalogue the notation, adopted by Struve and followed by most double star observers, puts the letter *A* at the left (telescopic view) corner of the tra-

pezium, *B* at the bottom (north), *C* at the top (south) and *D* at the right (east). The magnitudes given by Burnham are *A* 7.0, *B* 8.0, *C* 4.7, *D* 6.3. The upper (southernmost) star is thus the brightest of the four.

A New Law (?) of Planetary Distances.—In *Astronomische Nachrichten*, No. 5147, Mr. G. Armellini of the University of Pisa, proposes a new empirical law to represent the distances of the planets. His formula is simply

$$D = 1.53^{n},$$

in which D is the distance of the planet, and n its number in succession, beginning with $n = -2$ for Mercury, -1 for Venus, 0 for earth, 1 for Mars, etc. The representation of the distances is shown in the following table:

Planet	Calculated Distance	Observed Distance
Mercury	$1.53^{-2} = 0.427$	0.387
Venus	$1.53^{-1} = 0.653$	0.723
Earth	$1.53^{0} = 1.00$	1.00
Mars	$1.53^{1} = 1.53$	1.52
Asteroid Vesta	$1.53^{2} = 2.34$	2.36
Asteroid Camilla	$1.53^{3} = 3.58$	3.48
Jupiter	$1.53^{4} = 5.48$	5.20
Saturn	$1.53^{5} = 8.38$	9.54
	$1.53^{6} =$	vacant
Uranus	$1.53^{7} = 19.46$	19.2
Neptune	$1.53^{8} = 29.76$	30.1

Most of our readers are familiar with Bode's Law, which was the first attempt (made by Titius in 1772 and made known by Bode) to represent the planetary distances by a simple formula

$$D = 0.4 + 0.3 \times 2^{n}$$

This formula, as well as another derived by Gaussin,

$$D = 1/214.45 \times 1.7226^{n}$$

breaks down with the planet Neptune. The former was modified by Wurm,

$$D = 0.397 + 0.301 \times 2^{n}$$

and the latter by Bélot,

$$D = 0.28 + 1/214.5 \times 1.883^{n}$$

Armellini shows that his formula is more accurate than the others by comparing the mean errors of the calculated distances:

	Mean Error
Bode	3.08
Gaussin	1.37
Bélot	1.18
Armellini	0.473

They Still Say the Earth is Flat.—The following appeared in a recent Minneapolis daily newspaper:

Zion, Ill., Feb. 12.—Wilbur Glenn Voliva, speaking here today at services held in connection with the sixteenth anniversary of his administration, asserted that he was going to compel people to "accept either the Bible or modern astronomy." "They cannot accept both," said Mr. Voliva, who contends that the earth is flat, surrounded by a wall of ice and covered by a canopy in which are hung the sun, moon and stars.

Relief for Russian Astronomers.—We are glad to print the following Circular Letter, sent out from the Yerkes Observatory, in behalf of Russian astronomers, and the letter of Professor Belopolsky of the Pulkova Observatory, a translation of which has been sent us through the courtesy of Professor Frost. The need of Russian astronomers and their families is still very great, and it is very fitting that American astronomers should join in relieving that need as much as possible.

Dear Colleagues of American Observatories:

The response has been quick and generous to the circular letter which we sent out on March 21. We were able to mail this only to a few of the larger observatories, but Professor Wilson printed it in POPULAR ASTRONOMY for April and in this way it will reach other observatories and friends of astronomy in this country.

We have thus far received $588.50 and we have transmitted to the American Relief Association, Russian Department, 42 Broadway, New York, $330.00 in the form of food drafts to the eleven institutions mentioned in our circular letter, and to Mr. and Mrs. Cerasky formerly of the Moscow University Observatory. The Mount Wilson Observatory sent in March $50.00 for food packets through Dr. Vernon Kellogg to the Pulkova Observatory. Thus provision has been made (at this end) for the month of March and for the month of April, but we shall send again to all of the parties before the end of April, because the distress will probably be very acute at the time when the food packets are delivered.

It seems to us advisable to alter our provisional plan for having individual observatories sponsor separate Russian institutions. We have notified the recipients of the food packets that they come from American observatories participating in the plan, and we have given them the list of all the observatories that have contributed up to the time our letters were sent to Russia. We shall include later subscribers in our next letters to Russia. We are asking Mt Wilson hereafter to contribute directly to our general fund. We have invited the recipients of food packages to give us information as to their future needs. When their replies are received we shall distribute them to subscribers through circular letters or through the columns of POPULAR ASTRONOMY.

We are advised by the American Relief Administration that nothing can be sent to Russia except food-drafts.

There will be no overhead expense in connection with the work of this committee, but it will be preferable to receive installments of money in the form of bank drafts on New York rather than in personal checks when this is equally convenient to the sender.

Thanking you for your cordial participation in this American effort for a slight relief of our Russian colleagues and for their families, we are

Sincerely yours,

The Committee—EDWIN B. FROST
G. VAN BIESBROECK
OTTO STRUVE.

Yerkes Observatory, Williams Bay, Wis.
April 14, 1922.

Pulkova, Feb. 9, 1922.

My dear Frost:—

I have just received your kind letter of January 5, together with the reprint from POPULAR ASTRONOMY. I was very glad to hear again the news of yourself and your family. I was also greatly pleased to receive last week a copy of the Astrophysical Journal for January 1921.

I recently received a letter from Professor Schlesinger in which he informed me that the American Astronomical Society appointed (at the Swarthmore meeting in December 1921) a committee for the relief of Russian astronomers. I am deeply moved by this humanity which is highly developed indeed in America and its beneficent results are accomplished with great efficiency. God grant that

the Russian astronomers may highly appreciate this action, and that they will never forget what America has done for them!

We are passing through a severe winter without extreme cold, but very constant at about —15 to —20 degrees Centigrade since November, with only two or three days of thawing weather in the beginning of the winter, which were immediately followed by sharp cold weather. We have not been able to turn the dome of the thirty-inch refractor because the wheels became frozen so stiff to the rails. It is hardly possible to secure wood for heating and we are always in danger of being left without fuel. In other respects the life of the "Learned Men" has been much better than in the preceding year; first, because a much better provision has been made for them by the government, and second, the provision has been much better distributed. We may now say that we have enough, especially because much is sent to us in gifts from abroad. It is hard to say however what the Spring will bring forth, because the famine which has produced such terrible results in Eastern Russia may be possibly also felt here. We in Pulkova, as I have already written you, have a guarantee in the provisions, such as potatoes, which we have raised ourselves, enough to carry us through until the new harvest.

I have shown your letter to Tikhoff about the Astrophysical Journal, and he was well pleased with it. The arrival of the Astrophysical Journal shows that now we shall regularly receive foreign journals by mail; in fact the correspondence with foreign countries is much better cared for than the correspondence within Russia, because many letters are lost.

Unfortunately the political conditions prevent many Russians from returning to their homes. Among others is V.——, who cannot return to Pulkova. He was a very active worker; the war has spoiled his life work. Further the conditions of the astronomers in the Provinces of Russia are very bad too. The astronomers there often apply to Pulkova for positions, and this has been arranged in several instances. For instance, we now have with us Professor Pokrovsky first in Dorpat and later in Perm; and Mr. Schain from Tomsk and Matkewich from Taschkent. The astronomers of our branch observatories write us letters full of complaints as to the exceeding difficulty of life in the Provinces, particularly in Simeis. . . . Unfortunately the chambers of this observatory colony are entirely occupied and we cannot appoint any one else here until Summer, when there will be some rooms which can be occupied. Similar was the case of Mr. Yaschnoff who in 1919 went to Saratov in hopes of better conditions for his illness (asthma) and apparently for easier circumstances of life. He now wishes to return to Pulkova. From all this you will see that Pulkova is regarded by other astronomers as a true paradise.

I send with this my warmest greetings and heartiest thanks for your sympathy for the fate of Russian astronomers.

Sincerely,

BELOPOLSKY.

Corrigenda. — In the March number of POPULAR ASTRONOMY

p. 156, line 26, *for* "other" *read* "ether."

In the April number

p. 230, line	9,	*for*	±″.030	*read* ″.30.
	"	"	±″.029	" ″.29.
line	12,	"	±″.029	" ″.29.
	"	"	±″.028	" ″.28.
line	14,	"	±″.031	" ″.31.
	"	"	±″.030	" ″.30.

JOHNNY—"Say, grandpop, can I go out for a little while tonight? Bill Smith says there's a comet to be seen."

GRANDFATHER—"All right, but you be careful and don't go too near it."

POPULAR ASTRONOMY

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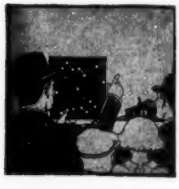

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